DOCUMENT RESUME

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TITLE	Military Curricula for Vocational & Technical Education. Refrigeration and Air Conditioning Specialist, Blocks VI-IX.
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SPONS AGENCY	Bureau of Occupational and Adult Education (DHEW/OE), Washington, D.C.
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EDRS PRICE	MF04/PC28 Plus Postage.
DESCRIPTORS	*Air Conditioning; *Air Conditioning Equipment; Behavioral Objectives; Course Descriptions; Curriculum Guides; *Equipment Maintenance; Equipment Utilization; High Schools; Learning Activities; Postsecondary Education; *Refrigeration; Refrigeration Mechanics; Study Guides; Trade and Industrial Education; Workbooks
IDENTIFIERS	Military Curriculum Project

ABSTRACT

This plan of instruction, study guides, and workbooks for a secondary-postsecondary-level course in refrigeration and air conditioning are one of a number of military-developed curriculum packages selected for adaptation to vocational instruction and curriculum development in a civilian setting. It is the third section of a three-part course (see Note for other sections) intended to train students in identification, location, function, installation, operational checking, servicing, repair, and maintenance of refrigeration and air conditioning systems. Dealing specifically with special refrigeration systems, water conditioning, absorption air conditioning (AC), AC controls, AC equipment, and evaporative cooling systems, this section contains four blocks covering 269.5 hours of instruction: Special Refrigeration System, Cooling Towers, Water Pumps, Water Conditioning, and Absorption AC System (5 lessons); AC Controls; (5 lessons); AC (7 lessons); and evaporative Cooling Systems (1 lesson). The plan of instruction contains an outline of the teaching steps, criterion objectives, lesson duration, correlation of tasks with a training standard, and support materials and guidance. Student materials include eight study guides with text information, objectives, review exercises, and references and eight workbooks with performance exercises. Commercial texts, military technical manuals, and audiovisual aids are suggested, but not provided. Materials may be adapted for individualized instruction or presented in a group setting. (YLB)

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CE 024 393

DraftingDrafting
DieteticsDietetics
Diesel RepairDiesel
Dental AssistingDental Assisting
Data ProcessingData Processing
Curriculum Development
Construction Trades
Carpentry Carpentry
Blueprint Reading
Aviation Mechanics
Auto Mechanics
WeldingWelding
Stenography Stenography
Small Equipment Repair
Radiology Radiology
Radio-TV Broadcasting
PrintingPrinting
Physical Therapy Assisting
PhotographyPhotography
NursingNursing
Metal Patternmaking
Medical Lab Assisting
Machine Shop
Management & Supervision
Heating & Air Conditioning
Food Service
Electronics
Electricity

Military Curricula for Vocational & Technical Education

REFRIGERATION AND AIR
CONDITIONING SPECIALIST

BLOCKS VI - IX

U S DEPARTMENT OF HEALTH,
EDUCATION & WELFARE
NATIONAL INSTITUTE OF
EDUCATION

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THE NATIONAL CENTER
FOR RESEARCH IN VOCATIONAL EDUCATION
THE OHIO STATE UNIVERSITY

This military technical training course has been selected and adapted by The Center for Vocational Education for "Trial Implementation of a Model System to Provide Military Curriculum Materials for Use in Vocational and Technical Education," a project sponsored by the Bureau of Occupational and Adult Education, U.S. Department of Health, Education, and Welfare.

MILITARY CURRICULUM MATERIALS

The military-developed curriculum materials in this course package were selected by the National Center for Research in Vocational Education Military Curriculum Project for dissemination to the six regional Curriculum Coordination Centers and other instructional materials agencies. The purpose of disseminating these courses was to make curriculum materials developed by the military more accessible to vocational educators in the civilian setting.

The course materials were acquired, evaluated by project staff and practitioners in the field, and prepared for dissemination. Materials which were specific to the military were deleted, copyrighted materials were either omitted or approval for their use was obtained. These course packages contain curriculum resource materials which can be adapted to support vocational instruction and curriculum development.

The National Center Mission Statement

The National Center for Research in Vocational Education's mission is to increase the ability of diverse agencies, institutions, and organizations to solve educational problems relating to individual career planning, preparation, and progression. The National Center fulfills its mission by:

- Generating knowledge through research
- Developing educational programs and products
- Evaluating individual program needs and outcomes
- Installing educational programs and products
- Operating information systems and services
- Conducting leadership development and training programs

FOR FURTHER INFORMATION ABOUT
Military Curriculum Materials
WRITE OR CALL
Program Information Office
The National Center for Research in Vocational Education
The Ohio State University
1960 Kenny Road, Columbus, Ohio 43210
Telephone: 614/486-3655 or Toll Free 800/848-4815 within the continental U.S. (except Ohio)

THE NATIONAL CENTER
FOR RESEARCH IN VOCATIONAL EDUCATION
The Ohio State University · 1960 Kenny Road · Columbus, Ohio 43210
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Military Curriculum Materials for Vocational and Technical Education

Information and Field Services Division

The National Center for Research in Vocational Education

Military Curriculum Materials Dissemination Is . . .

an activity to increase the accessibility of military-developed curriculum materials to vocational and technical educators.

This project, funded by the U.S. Office of Education, includes the identification and acquisition of curriculum materials in print form from the Coast Guard, Air Force, Army, Marine Corps and Navy.

Access to military curriculum materials is provided through a "Joint Memorandum of Understanding" between the U.S. Office of Education and the Department of Defense.

The acquired materials are reviewed by staff and subject matter specialists, and courses deemed applicable to vocational and technical education are selected for dissemination.

The National Center for Research in Vocational Education is the U.S. Office of Education's designated representative to acquire the materials and conduct the project activities.

Project Staff:

Wesley E. Budke, Ph.D., Director
National Center Clearinghouse

Shirley A. Chase, Ph.D.
Project Director

What Materials Are Available?

One hundred twenty courses on microfiche (thirteen in paper form) and descriptions of each have been provided to the vocational Curriculum Coordination Centers and other instructional materials agencies for dissemination.

Course materials include programmed instruction, curriculum outlines, instructor guides, student workbooks and technical manuals.

The 120 courses represent the following sixteen vocational subject areas:

- Agriculture
- Aviation
- Building & Construction Trades
- Clerical Occupations
- Communications
- Drafting
- Electronics
- Engine Mechanics
- Food Service
- Health
- Heating & Air Conditioning
- Machine Shop
- Management & Supervision
- Meteorology & Navigation
- Photography
- Public Service

The number of courses and the subject areas represented will expand as additional materials with application to vocational and technical education are identified and selected for dissemination.

How Can These Materials Be Obtained?

Contact the Curriculum Coordination Center in your region for information on obtaining materials (e.g., availability and cost). They will respond to your request directly or refer you to an instructional materials agency closer to you.

CURRICULUM COORDINATION CENTERS

EAST CENTRAL
Rebecca S. Douglass
Director
100 North First Street
Springfield, IL 62777
217/782-0759

MIDWEST
Robert Patton
Director
1515 West Sixth Ave.
Stillwater, OK 74704
405/377-2000

NORTHEAST
Joseph F. Kelly, Ph.D.
Director
225 West State Street
Trenton, NJ 08625
609/292-6562

NORTHWEST
William Daniels
Director
Building 17
Airdustrial Park
Olympia, WA 98504
206/753-0879

SOUTHEAST
James F. Shill, Ph.D.
Director
Mississippi State University
Drawer DX
Mississippi State, MS 39762
601/325-2510

WESTERN
Lawrence F. H. Zane, Ph.D.
Director
1776 University Ave.
Honolulu, HI 96822
808/948-7834

REFRIGERATION AND AIR CONDITIONING SPECIALIST

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REFRIGERATION AND AIR CONDITIONING SPECIALIST

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REFRIGERATION AND AIR CONDITIONING SPECIALIST, BLOCKS VI, VII, VIII, & IX

Classroom Course

11-8

eveloped by:

United States Air Force

evelopment and
eview Dates

September 25, 1975

Occupational Area:
Heating and Air Conditioning

Target Audiences:
Grades 11-adult

Print Pages:
689

Cost:
$14.00

Availability:
Military Curriculum Project, The Center for Vocational Education, 1960 Kenny Rd., Columbus, OH 43210

Contents:	Type of Materials: Lesson Plans:	Programmed Text:	Student Workbook:	Handouts:	Text Materials:	Audio-Visuals:	Instructional Design: Performance Objectives:	Tests:	Review Exercises:	Additional Materials Required:	Type of Instruction: Group Instruction:	Individualized:
			No. of pages									
Block VI – *Special Refrigeration Systems, Cooling Towers, Water Pumps, Water Conditioning, and Absorption Air Conditioning System*	●		77		●	★	●	★	●	★	●	
Block VII – *Air Conditioning Controls*	●		48		●	★	●		●	★	●	
Block VIII – *Air Conditioning*	●		116	★	●	★	●		●	★	●	
Block IX – *Evaporative Cooling System*	●		5		●		●		●	★	●	

★ **Materials are recommended but not provided.**

THE CENTER FOR VOCATIONAL EDUCATION
THE OHIO STATE UNIVERSITY

Expires July 1, 1978

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Course Description

This is the third section of a three-part course on refrigeration and air conditioning. The course trains students in identification, location, function, installation, operational checking, servicing, repair and maintenance of refrigeration and air conditioning systems. This section deals specifically with special refrigeration systems, water conditioning, absorption air conditioning, air conditioning controls, air conditioning equipment, and evaporative cooling systems. It contains four blocks covering 269.5 hours of instruction.

Block VI – *Special Refrigeration System, Cooling Towers, Water Pumps, Water Conditioning, and Absorption Air Conditioning System* contains five lessons covering 77 hours of instruction. The lesson topics and respective hours follow:

Multiple Refrigeration Systems (24 hours)
Cooling Towers (9 hours)
Water Pumps (6.5 hours)
Water Conditioning (12.5 hours)
Absorption Air Conditioning System (26 hours)

Block VII – *Air Conditioning Controls* has five lessons with 75 hours of instruction.

Air Compressing Equipment (2 hours)
Pneumatic Controls (34.5 hours)
Electrical Controls (22 hours)
Electronic Controls (16.5 hours)

Block VIII – *Air Conditioning* contains seven lessons covering 112.5 hours of instruction.

Air Conditioning Equipment (21 hours)
Air Flow Instruments (9.5 hours)
Psychrometrics (8 hours)
Heat Pumps (4 hours)
Package Air Conditioner (4 hours)
Direct Expansion Air Conditioning Systems (30.5 hours)
Indirect Expansion Air Conditioning Systems (36.5 hours)

Block IX – *Evaporative Cooling Systems* contains one lesson on the topic covering 4 hours of instruction. Three addition lessons covering communications security, maintenance management, and military publications were deleted because they are unsuitable for vocational program use.

This section contains both teacher and student materials. Printed instructor materials include a plan of instruction detailing the teaching steps by units of instruction, criterion objectives, the duration of the lessons, correlation of tasks with a training standard, and support materials and guidance. Student materials include eight study guides with text information, objectives, review exercises and references; and eight workbooks with performance exercises.

Text information is provided in the student study guides, however, several commercial texts and military technical manuals are referenced. Audiovisual aids suggested for use in the entire three part course include 15 films, 29 transparency sets and 29 charts. The materials in this section can be adapted for individualized instruction or presented in a group setting for courses on refrigeration, air conditioning and/or heating.

POI 3ABR54530
(PDS Code ATA)

PLAN OF INSTRUCTION
(Technical Training)

REFRIGERATION AND AIR CONDITIONING SPECIALIST

AIR TRAINING COMMAND

SHEPPARD TECHNICAL TRAINING CENTER

16 January 1976-Effective 17 March 1976 with class 760317

11-8

* See underscore in para 1 of Foreword, page i

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DEPARTMENT OF THE AIR FORCE
USAF School of Applied Aerospace Sciences (ATC)
Sheppard Air Force Base, Texas 76311

PLAN OF INSTRUCTION 3ABR54530
(PDS Code ATA)
16 January 1976

FOREWORD

1. PURPOSE: This publication is the plan of instruction (POI) when the pages shown on page A are bound into a single document. The POI prescribes the qualitative requirements for Course Number 3ABR54530, Refrigeration and Air Conditioning Specialist in terms of criterion objectives and teaching steps presented by units of instruction and shows duration, correlation with the training standard, and support materials and guidance. When separated into units of instruction, it becomes Part I of the lesson plan. This POI was developed under the provisions of ATCR-[illegible] Instructional System Development, and ATCR 52-7, Plans of Instruction and Lesson Plans.

2. COURSE DESIGN/DESCRIPTION. The instructional design for this course is Group Lock Step. The course trains airmen to perform duties prescribed in AFM-39-1 for Refrigeration and Air Conditioning Specialists, AFSC 54530. Training includes the use of AF publications and forms, and commercial manuals related to identification, location, function, installation, operational checking, servicing, repair and maintenance of refrigeration and air conditioning systems. The course also includes water analysis and conditioning. In addition, related training is provided on driver education, troop information program, commander's call/briefings, etc.

3. TRAINING EQUIPMENT. The number shown in parentheses after equipment listed as Training Equipment under SUPPORT MATERIALS AND GUIDANCE is the planned number of students assigned to each equipment unit.

4. REFERENCES. This plan of instruction is based on Specialty Training Standard, 54530/50/70, 16 April 1973, and Course Chart 3ABR54530, 15 January 1976.

FOR THE COMMANDER

LEONARD A. HAMILTON, Col, USAF
Chief, Dept of Civil Engineering Training

Supersedes Plan of Instruction 3ABR54530, 15 August 1973
CPR: Department of Civil Engineering Training
DISTRIBUTION: Listed on page A

PLAN OF INSTRUCTION/LESSON PLAN PART I

NAME OF INSTRUCTOR	COURSE TITLE Refrigeration and Air Conditioning Specialist
BLOCK NUMBER VI	BLOCK TITLE Special Refrigeration System, Cooling Towers, Water Pumps Water Conditioning, and Absorption Air Conditioning System

1 COURSE CONTENT	2 TIME
1. Multiple Refrigeration Systems	24 (18/6) Day 46 thru 48
a. Using assigned trainer, service, adjust and operate a single temperature multiple evaporator system to conditions specified in workbook. STS: 10e(6), 12a, 12c, 14a, 14e, 14i, 14k, 15a(2), 15a(3), 16a, 16c, 16f, 17a(9), 17c(4). Meas: W, PC	(6/2) Day 46
(1) Application	
(2) Major components	
(3) Principles of operation	
b. Using assigned trainer, service, adjust and operate a solenoid valve multiple evaporator system to conditions specified in workbook. STS: 10e(2)(d), 10e(6), 12a, 12c, 14a, 14e, 14i, 14k, 15a(2), 15a(3), 16a, 16b, 16c, 16f, 17a(9), 17c(4). Meas: W, PC	(3/1) Day 47
(1) Applications	
(2) Solenoid valves	
(3) Major components in solenoid valve system	
(4) Principle of operation	
c. Using assigned trainer, service, adjust and operate an evaporator pressure regulator multiple evaporator system to conditions specified in workbook. STS: 12a, 12c, 14a, 14e, 14i, 14k, 15a(2), 15a(3), 16c, 16d, 16e, 16f, 17a(9), 17c(4). Meas: W, PC	(3/1) Day 47
(1) Applications	

SUPERVISOR APPROVAL OF LESSON PLAN (PART II)

SIGNATURE AND DATE	SIGNATURE AND DATE

PLAN OF INSTRUCTION NUMBER	DATE	PAGE NO.
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COURSE CONTENT

(2) Evaporator pressure regulator

(3) Major components in evaporator pressure regulator valve system

(4) Principle of operation

d. Using assigned trainer, service, adjust and operate a multiple compressor system to conditions specified in workbook. STS: 10e(6), 12a, 12c, 14a, 14e, 14i, 14k, 15a(2), 15a(3), 16a, 16b, 16c, 16f, 17a(9), 17c(4)
Meas: W, PC

(6/2)
Day 48

(1) Multiple compressor system: piped in parallel

(a) Applications

(b) Major components

(c) Principles of operation

(2) Temperature ranges and problems encountered in each

(3) Multiple compressor system: piped in series

(a) Application

(b) Intercooler

(c) Subcooler

(4) Multiple compressor system: Cascade

(a) Application

(b) Elementary

(c) Two stage

PLAN OF INSTRUCTION/LESSON PLAN PART I (Continuation Sheet)

COURSE CONTENT

SUPPORT MATERIALS AND GUIDANCE

Student Instructional Materials
SG 3ABR54530-VI-1 thru -3, Multiple Refrigeration Systems, Evaporative Cooling Towers, and Water Pump
WB 3ABR54530-VI-1-P1, Single Temperature Multiple Evaporator System
WB 3ABR54530-VI-1-P2, Solenoid Valve Multiple Evaporator System
WB 3ABR54530-VI-1-P3, Evaporator Pressure Regulator Multiple Evaporator System
WB 3ABR54530-VI-1-P4, Multiple Compressor Systems

Audio Visual Aids
Transparencies, Set, Multiple Refrigeration Systems

Training Equipment
Trainer, Multiple Evaporator Refrigeration System ([illegible])
Trainer, Multiple Compressor System (12)
Demonstrator, Solenoid Valve (12)
Tool Kit (2)

Training Methods
Discussion/Demonstration (6 hrs)
Performance (12 hrs)
CTT Assignment (6 hrs)

Multiple Instructor Requirements
Safety, Equipment, Supervision (2)

Instructional Guidance
Electrical safety will be stressed and protective equipment will be used when working on trainers to prevent injury to students. Outside Assignment: Day 46, direct students to review WBs VI-1-P1 and P2; Day 47, P3; Day 48, P4.

MIR: Two instructors are required for 11 hours of student performance (4 hours in Day 46, 4 hours in Day 47, and 3 hours in Day 48).

NAME OF INSTRUCTOR	COURSE TITLE Refrigeration and Air Conditioning Specialist
BLOCK NUMBER VI	BLOCK TITLE Special Refrigeration System, Cooling Towers, Water Pumps Water Conditioning, and Absorption Air Conditioning System

1 COURSE CONTENT	2 TIME
2. Cooling Towers	8 (6/2) Day 49
a. Using the diagram in workbook correctly identify all components and trace the flow of air and water through a cooling tower. STS: 22a Meas: W	(2/1)
(1) Purpose of cooling towers	
(2) Natural draft cooling tower	
(a) Major components	
(b) Construction features	
(3) Forced draft cooling tower	
(a) Major components	
(b) Construction features	
b. Using materials provided, correctly identify installation, cleaning, and maintenance procedures for cooling towers and evaporative condensers. Also determine bleed-off and make-up water requirements to within + 5% of stated specifications. STS: 22a, 22b, 22c Meas: W	(2/0.5)
(1) Bleed-off water	
(2) Make-up water	
c. Using the diagram in workbook, identify the three methods of capacity control of a cooling tower. STS: 22a, 22d Meas: W	(2/0.5)
(1) Three-way regulating valve	
(2) Temperature controls	
(3) Damper controls	

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SUPPORT MATERIALS AND GUIDANCE

Student Instructional Materials

SG 3ABR54530-VI-1 thru -3, Multiple Refrigeration Systems, Evaporative Cooling Towers, and Water Pump
WB 3ABR54530-VI-2-P1, Evaporative Cooling Tower Components
WB 3ABR54530-VI-2-P2, Bleed-Off and Make-Up Water Requirements
WB 3ABR54530-VI-2-P3, Evaporative Cooling Tower Capacity Control

Audio Visual Aids

Transparencies, Set, Cooling Towers

Training Equipment

None

Training Methods

Discussion/Demonstration (4.5 hrs)
Performance (1.5 hrs)
CTT Assignment (2 hrs)

Instruction Guidance

Insure that students complete work projects and show students different types of cooling towers outside Building 1927. Outside Assignment: Day 49, direct students to review WBs VI-2-P1 thru P3.

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PLAN OF INSTRUCTION/LESSON PLAN PART I

NAME OF INSTRUCTOR	COURSE TITLE
	Refrigeration and Air Conditioning Specialist

BLOCK NUMBER	BLOCK TITLE
VI	Special Refrigeration System, Cooling Towers, Water Pumps Water Conditioning, and Absorption Air Conditioning System

1 COURSE CONTENT	2 TIME
3. Water Pumps	6.5 (4.5/2) Day 50
a. Using assigned trainer, correctly identify major components of a centrifugal water pump and state the purpose and minor maintenance of each component. STS: 23a, __ Meas: W	(2.5/1)
(1) Applications	
(2) Major components and purpose of each	
(3) Pressure characteristics of centrifugal pumps	
b. Using a dial indicator, align a flexible coupling on a centrifugal water pump to conditions specified in workbook. STS: 5b, 5d, 23b, 23c, 23d, 23e, 23f. Meas: W, PC	(2/1)
(1) Installation and alignment	
(2) Check operation of water pump	
(3) Removal of water pump	
(4) Repair of water pump	
(5) Adjust and replace pump packing	

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COURSE CONTENT

SUPPORT MATERIALS AND GUIDANCE

Student Instructional Materials
SG 3ABR54530-VI-1 thru -3, Multiple Refrigeration Systems, Evaporative Cooling Towers, and Water Pumps
WB 3ABR54530-VI-3-P1, Identification of Centrifugal Water Pump Components
WB 3ABR54530-VI-3-P2, Align Flexible Coupling Using a Dial Indicator

Audio Visual Aids
Transparencies, Set, Water Pump
Training Film: TVS-56-6, Centrifugal Pump Maintenance

Training Equipment
Trainer, Centrifugal Water Pump (12)
Trainer, Centrifugal Water Pump (4)
Dial Indicator (4)

Training Methods
Discussion/Demonstration (1.5 hrs)
Performance (2.5 hrs)
Training Film (0.5 hr)
CTT Assignment (2 hrs)

Instructional Guidance
Emphasize safety when working on equipment; watch out for pulleys, shafts, and belts. Use dial indicators with great care; they are precision instruments. Outside Assignment: Day 50, direct students to review WBs VI-3-P1 and P2.

PLAN OF INSTRUCTION/LESSON PLAN PART I

NAME OF INSTRUCTOR

COURSE TITLE Refrigeration and Air Conditioning Specialist

BLOCK NUMBER VI

Special Refrigeration System, Cooling Towers, Water Pumps Water Conditioning, and Absorption Air Conditioning

1 COURSE CONTENT	2 TIME
4. Measurement Test and Test Critique	1.5 (1.5/0) Day 50
5. Water Conditioning	12.5 (9.5/3) Days 51 and 52
a. Given a sample of water, chemically treat it to prevent corrosion by adjusting the pH to 8, +/-1. STS: 24a, 24b, 24c Meas: W, PC	(3/1) Day 51
(1) Laboratory safety	
(2) Collection and preparation of test samples	
(3) Potential Hydrogen scale	
(a) Explanation of pH scale	
(b) pH below 7: Acid	
(c) pH above 7: Base	
(4) Litmus test	
(5) P-indicator test	
(6) Color Comparator test	
(7) Corrosion	
(a) Definition	
(b) Causes of corrosion	

SUPERVISOR APPROVAL OF LESSON PLAN (PART II)

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(c) Effects of corrosion

(d) Treatment and prevention of corrosion

(1) Removal

(2) Prevention

b. Given a sample of water, chemically treat it to prevent scale by adjusting the phosphate content to 40, ±10 ppm. STS: 24a, 24b, 24c. Meas: W, PC (3/1) Day 51

(1) Definition

(2) Factors required to form scale

(3) Effects of scale

(4) Treatment and prevention of scale

(a) Removal

(b) Prevention

(5) Phosphate test

c. Given a sample of water, chemically treat it to prevent algae by adjusting the chlorine content to 1.5 to 3 ppm. STS: 24a, 24b, 24c. Meas: W, PC (2/0.5) Day 52

(1) Definition

(2) Factors required for the growth of algae

(3) Effects of algae

(4) Treatment and prevention of algae

(5) Chlorine test

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PLAN OF INSTRUCTION/LESSON PLAN PART I (Continuation Sheet)

COURSE CONTENT

d. Using a schematic correctly trace the flow of water through a water conditioning chemical feeder. STS: 22f Meas: W (1.5/0.5) Day 52

(1) Purpose of chemical feeders

(2) Types of chemical feeders

(3) Installation and servicing chemical feeders

SUPPORT MATERIALS AND GUIDANCE

Student Instructional Materials
SG 3ABR54530-VI-5 thru -6, Water Conditioning and Absorption Air Conditioning System
WB 3ABR54530-VI-5-P1, Chemically Treat Water for Corrosion
WB 3ABR54530-VI-5-P2, Chemically Treat Water for Scale
WB 3ABR54530-VI-5-P3, Chemically Treat Water for Algae
WB 3ABR54530-VI-5-P4, Identify Components of a Water Conditioning System

Audio Visual Aids
Transparencies, Set, Water Treatment
Prenarrated Slides: ATS 54-21, Cooling Water Treatment

Training Equipment
Color Comparator (2)
Laboratory Equipment (2)

Training Methods
Discussion/Demonstration (4.5 hrs)
Performance (5 hrs)
CTT Assignment (3 hrs)

Multiple Instructor Requirements
Safety (2)

Instructional Guidance
Emphasize chemical safety and wearing of protective clothing. Caution students concerning the handling of glassware. Outside Assignment: Day 51, direct students to review WBs VI-5-P1 thru P3; Day 52, P4.

MIR: Two instructors are needed for 4 hours of student performance (3 hours in Day 51, and 1 hour in Day 52)

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PLAN OF INSTRUCTION/LESSON PLAN PART I

NAME OF INSTRUCTOR	COURSE TITLE
	Refrigeration and Air Conditioning Specialist

BLOCK NUMBER	BLOCK TITLE
VI	Special Refrigeration System, Cooling Towers, Water Pumps Water Conditioning, and Absorption Air Conditioning

1 COURSE CONTENT	2 TIME
6. Absorption Air Conditioning System	26 (19/7) Days 52 thru 55
a. Using workbook procedures and a diagram, identify major components of a lithium bromide absorption air conditioning system. STS: 20b, 20c. Meas: W	(2.5/1) Day 52
(1) Historical development of absorption systems	
(2) Applications of the lithium bromide system	
(3) System characteristics	
(4) Major components	
b. Using workbook procedures and a diagram, trace refrigerant and absorbant flow in a lithium bromide absorption air conditioning system. STS: 20a, 20b, 20c. Meas: W	(4/1) Day 53
(1) Refrigerant flow	
(2) Absorbant flow	
c. Given a pressure temperature chart and a manometer reading determine the condition of the vacuum in a lithium bromide absorption system to within 0.1 inch of mercury absolute. STS: 20a, 20d(1), 20d(2), 20i. Meas: W	(2/1) Day 53
(1) Vacuum tests	
(a) Standing vacuum test	
(b) Running vacuum test	
(2) Leak checking	

SUPERVISOR APPROVAL OF LESSON PLAN (PART II)

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d. Using workbook project, list the procedures for charging and removing refrigerant and absorbant from a lithium bromide absorption system. STS: 20c, 20e(1), 20e(2), 20g, 20i. Meas: W — (2/1) Day 54

(1) Charging refrigerant and/or absorbant

(2) Removing refrigerant and/or absorbant

e. Using a solution concentration chart and following instructions in workbook, determine the solution concentration of a lithium bromide system within 5% accuracy. STS: 20c, 20f, 20h, 20i. Meas: W — (2/0.5) Day 54

(1) Purpose

(2) Procedures

f. Using a wiring diagram, trace the sequence of operation for start-up and shut-down of a lithium bromide absorption system. STS: 20a, 20b, 20c. Meas: W — (2/0.5) Day 54

(1) Types of control systems

(2) Control operation

g. Given a troubleshooting chart, complete workbook project by stating troubleshooting procedures on a lithium bromide system. STS: 20a, 20b, 20c, 20h, 20i. Meas: W — (4.5/2) Day 55

(1) Purpose of troubleshooting charts

(2) Troubleshooting a lithium bromide system

SUPPORT MATERIALS AND GUIDANCE

Student Instructional Materials
SG 3ABR54530-VI-5 thru -6, Water Conditioning and Absorption Air Conditioning System
WB 3ABR54530-VI-6-P1, Identification of Major Components of a Lithium Bromide Absorption System
WB 3ABR54530-VI-6-P2, Refrigerant and Absorbant Flow
WB 3ABR54530-VI-6-P3, Checking Machine Vacuum
WB 3ABR54530-VI-6-P4, Adding and Removing of Refrigerant and Absorbant
WB 3ABR54530-VI-6-P5, Absorbant Concentration
WB 3ABR54530-VI-6-P6, Lithium Bromide Air Conditioning Wiring Diagram
WB 3ABR54530-VI-6-P7, Troubleshooting Chart

Audio Visual Aids
Transparencies, Set, Absorption
Training Film: CE-9, Lithium Bromide Air Conditioner (12)

Training Equipment
None

Training Methods
Discussion/Demonstration (12.5 hrs)
Performance (6 hrs)
Training Film (0.5 hr)
CTT Assignment (7 hrs)

Instructional Guidance
The students are to be instructed that lithium bromide is corrosive when exposed to air. All tools must be washed with fresh water and then oiled. If lithium bromide gets into eyes, rinse eyes with water, then consult a physician. Do not syphon lithium bromide with a hose. Outside Assignment: Day 52, direct students to review WB VI-6-P1; Day 53, P2 and P3, Day 54 P4 thru P6; Day 55, P7.

7. Measurement Test and Test Critique 1.5
(1.5/0)
Day 55

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PLAN OF INSTRUCTION/LESSON PLAN PART I

NAME OF INSTRUCTOR	COURSE TITLE Refrigeration and Air Conditioning Specialist
BLOCK NUMBER VII	BLOCK TITLE Air Conditioning Controls

1 COURSE CONTENT	2 TIME
1. Air Compressing Equipment	2 (2/0) Day 56
a. Using workbook procedures, identify major components of air compressor system. STS: 13f(2) Meas: W	(1/0)
(1) Major components and purposes of each	
(2) Safety devices	
b. Using appropriate technical data and the assigned trainer for illustrative purposes, correctly state the operator's inspection, service, and maintenance procedures for an air compressor system. STS: 13f(3), 13f(4) Meas: W	(1/0)
(1) Service and maintenance	
(2) Operator's inspection	

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PLAN OF INSTRUCTION/LESSON PLAN PART I (Continuation Sheet)

COURSE CONTENT

SUPPORT MATERIALS AND GUIDANCE

Student Instructional Materials
SG 3ABR54530-VII-1 and -2, Air Compressing Equipment and Penumatic Controls
WB 3ABR54530-VII-1-P1, Identifying Components of an Air Compressor System
WB 3ABR54530-VII-1-P2, Operator's Service and Maintenance of an Air Compressor System

Audio Visual Aids
Transparencies, Set, Air Compressor

Training Equipment
Trainer, Refrigeration Controls (2)
Trainer, Pneumatic Controls (12)

Training Methods
Discussion/Demonstration (1 hr)
Performance (1 hr)

Multiple Instructor Requirements
Safety, Equipment, Supervision (2)

Instructional Guidance
Stress safety precautions involved in servicing an air compressor system: electrical, compressed air, safety relief valves, and belts.

MIR: Two instructors are required for one half hour of student performance.

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PLAN OF INSTRUCTION/LESSON PLAN PART I

NAME OF INSTRUCTOR	COURSE TITLE Refrigeration and Air Conditioning Specialist
BLOCK NUMBER VII	BLOCK TITLE Air Conditioning Controls

1 COURSE CONTENT	2 TIME
2. Pneumatic Controls	34.5 (26.5/ (8) Days 56 thru 60
a Using a diagram, identify the major pneumatic control terms of a pneumatic control system STS: 15e(1), 15e(2) Meas: W	(4/1.5) Day 56
(1) Purpose and use of pneumatic controls	
(2) Major pneumatic control terms	
b. Using assigned trainer, determine the midspring range of a pneumatic valve and adjust the valve to that position in accordance with procedures provided in workbook. STS: 15e(2), 15e(3), 15e(4) Meas: W, PC	(2/1) Day 57
(1) Applications	
(2) Major components	
(3) Installation and adjustment	
c. Using assigned trainer, determine the midspring range of a pneumatic damper operator and adjust the damper operator to that position in accordance with procedures provided in workbook. STS: 15e(3), 15e(4) Meas: W, PC	(2/0) Day 57
(1) Applications	
(2) Major components	
(3) Installation and adjustment	

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d. Using assigned trainer, operate and adjust a pilot positioner in accordance with procedures provided in workbook. STS: 15e(2), 15e(3), 15e(4). Meas: W, PC (2/1.5) Day 57

(1) Applications

(2) Components and construction features

(3) Adjustments

e. Using assigned trainer, calibrate and adjust a pneumatic room thermostat to maintain 70, ±2°F. STS: 15e(2), 15e(3), 15e(4) Meas: W, PC (6/2) Day 58

(1) Applications

(2) Major components and function of each

(3) Installation procedures

(4) Calibration

f. Using assigned trainer, calibrate and adjust a pneumatic heating-cooling thermostat to maintain 70, ±2° F. STS: 15e(2), 15e(3), 15e(4) Meas: W, PC (6/2) Day 59

(1) Application

(2) Heating-cooling thermostat

(3) Switch-over mechanism

g. Using assigned trainer, calibrate and adjust a pneumatic non-bleed controller to maintain 70, ±2°F. STS: 15e(2), 15e(3), 15e(4) Meas: W, PC (4.5/0) Day 60

(1) RP-908A Controller

(2) LP-914A Sensor

COURSE CONTENT

SUPPORT MATERIALS AND GUIDANCE

Student Instructional Materials

SG 3ABR54530-VII-1 and -2, Air Compressing Equipment and Pneumatic Controls
WB 3ABR54530-VII-2-P1, Identification of Control Terms and Components of a Pneumatic Control System
WB 3ABR54530-VII-2-P2, Determining the Midspring Range of a Pneumatic Valve
WB 3ABR54530-VII-2-P3, Adjustments of a Pneumatic Damper Operator
WB 3ABR54530-VII-2-P4, Operation and Adjustment of a Pilot Positioner
WB 3ABR54530-VII-2-P5, Calibrating a Pneumatic Room Thermostat
WB 3ABR54530-VII-2-P6, Calibrating a Pneumatic Heating - Cooling Thermostat
WB 3ABR54530-VII-2-P7, Calibrating of a Non-Bleed Controller

Audio Visual Aids

Transparencies, Set, Pneumatic Control
Training Film: TF5658a, Pneumatic Temperature Controls - Theory
Training Film: TF5658b, Pneumatic Temperature Control Devices
Charts, Set, Penumatic Controls

Training Equipment

Trainer, Refrigeration Controls (2)
Bench Items:
    Johnson Kit (2)
    Room Thermostat (2)
    Sling Psychrometer (12)
    Room Humidistat (12)
    Heating-Cooling Thermostat (2)
    Pneumatic Valve (2)
    Pneumatic Damper Operator (2)
    Pilot Positioner (2)
    Nonbleed Controller (2)
    Temperature Sensor (2)

Training Methods

Discussion/Demonstration (15 hrs)
Performance (10.5 hrs)
Training Films (1 hr)
CTT Assignment (8 hrs)

Multiple Instructor Requirements

Safety, Equipment, Supervision (2)

Instructional Guidance
Emphasize safety when working with pneumatic equipment. Have each student complete each performance following procedures as stated in the workbook. Emphasize to students that they must give the trainers time to react to control calibration and adjustments. Outside Assignment: Day 56, direct student to review WB VII-2-P1; Day 57, P2 and P3; Day 58, P4 and P5; Day 59, P6 and P7.

MIR: Two instructors are required for 9.5 hours during student performance (3 hours in Day 57, 2 hours in Day 58, 2 hours in Day 59, and 2.5 hours in Day 60).

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PLAN OF INSTRUCTION/LESSON PLAN PART I

NAME OF INSTRUCTOR	COURSE TITLE
	Refrigeration and Air Conditioning Specialist

BLOCK NUMBER	BLOCK TITLE
VII	Air Conditioning Controls

1 COURSE CONTENT	2 TIME
3. Measurement Test and Test Critique	1.5 (1.5/0) Day 60
4. Electric Controls	22 (16/6) Days 61, 62 and 63
a. Using assigned trainer, and multimeter, locate opens and shorts in accordance with workbook procedures. STS: 10g(2), 15c(4) Meas: W, PC	(2/0.5) Day 61
(1) Applications of electric controls	
(2) Locating opens and shorts	
b. Using components supplied by instructor, connect, adjust and operate a series-20 control loop in accordance with procedures provided in workbook. STS: 15c(1)(a), 15[illegible]), 15c(3), 15c(4), 15c(5). Meas: W, PC	(4/1.5) Day 61
(1) Applications	
(2) Major components of series-20 control loop	
(3) Current flow	
c. Using components supplied by instructor, connect, adjust and operate a series-40 or a series-80 control loop in accordance with procedures provided in workbook. STS: 15c(1)(a), 15c(1)(b), 15c(2), 15c(3), 15a(4), 15c(5) Meas: W, PC	(3/1) Day 62
(1) Application	
(2) Comparison: series-40 and series-80 control loops	

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(3) Major components

(4) Operation of a "fail safe" device

(5) Current flow

d. Using components supplied by instructor, connect, adjust and operate a series-60 control loop in accordance with procedures provided in workbook. STS: 15c(1)(a), 15c(1)(b), 15c(2), 15c(3), 15c(4), 15c(5). Meas: W, PC — (3/1) Day 62

(1) Application

(2) Major components

(3) Current flow

e. Using components supplied by instructor, connect, adjust, operate and troubleshoot a series-90 control loop in accordance with procedures provided in workbook. STS: 10e(1)(d), 15c(1)(b), 15c(2), 15c(3), 15c(4), 15c(5) Meas: W, PC — (4/2) Day 63

(1) Application

(2) Major components

(3) Bridge circuit

(4) Current flow

(5) Calibration

(6) Troubleshooting

SUPPORT MATERIALS AND GUIDANCE

Student Instructional Materials
SG 3ABR54530-VII-4 and -5, Electrical and Electronic Controls
WB 3ABR54530-VII-4-P1, Troubleshooting Electrical Controls
WB 3ABR54530-VII-4-P2, Operation and Adjustment of Series-20 Controls
WB 3ABR54530-VII-4-P3, Operation and Adjustment of Series-40 and -80 Control Loops
WB 3ABR54530-VII-4-P4, Operation and Adjustment of Series-60 Control Loop
WB 3ABR54530-VII-4-P5, Operation, Adjustment and Troubleshooting of Series-90 Controls

Audio Visual Aids
Transparencies, Set, Electrical Controls
Charts, Set, Electrical Controls
Prenarrated Slide: ATS 54-14, Series-20 Motorized Valve

Training Equipment
Trainer, Continuity Test (6)
Multimeter (2)
Bench Items:
    Electrical Controller Series-20 (2)
    Electrical Controller Series-40 (2)
    Electrical Controller Series-60 (2)
    Pressuretrol Series-90 (2)
    Series-20 Control Motor (2)
    Series-40 Control Motor (2)
    Series-60 Control Motor (2)
    Series-80 Control Motor (2)
    Series-90 Control Motor (2)

Training Methods
Discussion/Demonstration (7.5 hrs)
Performance (8.5 hrs)
CTT Assignment (6 hrs)

Multiple Instructor Requirements
Safety, Equipment, Supervision (2)

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PLAN OF INSTRUCTION/LESSON PLAN PART I (Continuation Sheet)

COURSE CONTENT

Instructional Guidance

As a safety precaution, students will remove all jewelry while completing performances. Have students complete outside assignments appropriate to lesson. Outside Assignment: Day 61, direct students to review WBs VII-4-P1 and P2; Day 62, P3 and P4; Day 63, P5.

MIR: Two instructors are needed for 7.5 hours during student performance (2 hours in Day 61, 3.5 hours in Day 62, and 2 hours in Day 63).

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PLAN OF INSTRUCTION/LESSON PLAN PART I

NAME OF INSTRUCTOR	COURSE TITLE
	Refrigeration and Air Conditioning Specialist

BLOCK NUMBER	BLOCK TITLE
VII	Air Conditioning Controls

1 COURSE CONTENT	2 TIME
5. Electronic Controls	16.5 (12.5/4) Days 63 thru 65
a. Using diagram, identify components and state purpose of conventional and solid state devices, completing without error at least 80% of the workbook project. STS: 10e(1)(d), 15d(1), 15d(2), 15d(3), 15d(4), 15d(5), 15d(7). Meas: W	(8/2) Days 63 and 64
(1) Application of electronic controls	
(2) Conventional (tube) type electronic equipment	
(a) Components	
(b) Rectification	
(c) Amplification	
(3) Solid state electronic equipment	
(a) Principle of operation	
(b) Components	
(c) Rectification	
(d) Amplification (transistor)	
(4) Electronic power supply	

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COURSE CONTENT

b. Using assigned trainer, wire, adjust and troubleshoot an electronic humidity control loop. STS: 15d(1), 15d(2), 15d(3), 15d(4), 15d(5), 15d(6), 15d(7), 15d(8), 15d(9), 15d(10) Meas: W	(4.5/2) Day 65

(1) Operation of the phase detector circuit

(2) Major components of an electronic control loop

(3) Installation and calibration

SUPPORT MATERIALS AND GUIDANCE

Student Instructional Materials
SG 3ABR54530-VII-4 and -5, Electrical and Electronic Controls
WB 3ABR54530-VII-5-P1, Identification and Purpose of Conventional and Solid-State Devices
WB 3ABR54530-VII-5-P2, Wire and Operate an Electronic Humidity Control Loop

Audio Visual Aids
Transparencies, Set, Electronic Controls
Charts, Set, Electronic Controls
Training Film: TF4145, Basic Electronics as Applied to Electronic Control Systems
Training Film: TFI-5250A, Transistors - PN Junction Fundamentals

Training Equipment
Trainer, Humidity Control System (4)
Demonstrator, Electronic Thermostat (12)
Demonstrator, Triode Tube (12)
Demonstrator, Gold Leaf (12)
Multimeter, (2)

Training Methods
Discussion/Demonstration (7.75 hrs)
Performance (4 hrs)
Training Films (0.75 hr)
CTT Assignment (4 hrs)

Multiple Instructor Requirements
Safety, Equipment, Supervision (2)

PLAN OF INSTRUCTION/LESSON PLAN PART I (Continuation Sheet)

COURSE CONTENT

Instructional Guidance
As a safety precaution, students will remove all jewelry while completing performance. Outside Assignment: Day 64, direct students to review WBs VII-5-P1 and P2; Day 65, review Block VII materials.

MIR: Two instructors are needed for 4 hours during student performance (2 hours in Day 64 and 2 hours in Day 65).

6. Related Training (identified in course chart) 2

7. Measurement Test and Test Critique 1.5
(1.5/0)
Day 65

PLAN OF INSTRUCTION/LESSON PLAN PART I

NAME OF INSTRUCTOR	COURSE TITLE
	Refrigeration and Air Conditioning Specialist

BLOCK NUMBER	BLOCK TITLE
VIII	Air Conditioning

1 COURSE CONTENT	2 TIME
1. Air Conditioning Equipment	21 (16/5) Days 66 thru 68
a. Using workbook, identify major components of the air conditioning trainers as to their type, purpose and principle of operation. STS: 18, 19a, 19b, 19t(1), 19t(2), 19v(1), 19v(2). Meas: W, PC	(4/1) Day 66
(1) Purpose and fundamentals of air conditioning	
(2) Types of air conditioning equipment	
(3) Purpose and operation of major components	
(4) Purpose and operation of associated components	
b. Using window air conditioner trainer and tools provided, operate, troubleshoot, and service following the workbook procedures. STS: 10b, 19e, 19f, 19g, 19h, 19t(2), 19v(2), 21c(1), 21c(2), 21c(3), 21c(5). Meas: W, PC	(8/3) Days 66 and 67
(1) Major components and principles of operation of window air conditioners	
(2) Methods of control	
(3) Operation and troubleshooting of window air conditioners	
(4) Servicing procedures for window air conditioners	
(5) Installation techniques and procedures	

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COURSE CONTENT

c. Using workbook and residential air conditioner trainer, identify major components, their functions, and trace electrical circuits. STS: 19b, 19g, 19v(2) Meas: W, PC (4/1) Day 68

(1) Air Circulating system components

(2) Furnace system components

(3) Cooling system components

(4) Electrical circuits

(5) Performance checks

SUPPORT MATERIALS AND GUIDANCE

Student Instructional Materials
SG 3ABR54530-VIII-1 thru -3, Typical Air Conditioning Equipment and Psychrometrics
WB 3ABR54530-VIII-1-P1, Select Fan, Filter and Insulation
WB 3ABR54530-VIII-1-P2, Familiarization of Window Air Conditioners
WB 3ABR54530-VIII-1-P3, Familiarization of Residential Heating and Cooling Systems
WB 3ABR54530-VIII-1-P4, Heating and Cooling Wiring Diagrams

Audio Visual Aids
Charts, Set, Air Conditioning Equipment
Transparencies, Set, Window and Residential Air Conditioning
Training Film: TF 6361, Home Heating and Air Conditioning Control Systems
Prenarrated Slides: Room Air Conditioners

Training Equipment
Trainer, Insulation Demonstrator (12)
Trainer, Drum Control Filter (2)
Trainer, Prefilter and Deep Bed (12)
Trainer, Fan Centrifugal (12)
Trainer, Fan Vaneaxial (12)
Trainer, Air Conditioner, Window (2)
Trainer, Heating and Cooling Residential (12)

Training Methods
Discussion/Demonstration (8.5 hrs)
Performance (7 hrs)
Training Film (0.5 hr)
CTT Assignment (5 hrs)

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COURSE CONTENT

Multiple Instructor Requirements
Safety, Supervision (2)

Instructional Guidance
Electrical safety should be stressed in this area, and protective items must be worn when working on trainers to prevent injury due to a liquid refrigerant accident. Outside Assignments: Day 66, direct students to review WBs VIII-1-P1 and P2; Day 67, P3; Day 68, P4.

MIR: Two instructors are needed for 4.5 hours during student performance in Day 67.

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PLAN OF INSTRUCTION/LESSON PLAN PART I

NAME OF INSTRUCTOR	COURSE TITLE Refrigeration and Air Conditioning Specialist
BLOCK NUMBER VIII	BLOCK TITLE Air Conditioning

1 COURSE CONTENT	2 TIME
2. Air Flow Instruments	9.5 (7/2.5) Days 68 and 69
a. Using air flow instrument and selected air conditioner, determine CFM to within five percent accuracy. STS: 19u(1), 19u(2). Meas: W, PC	(3/1) Days 68 and 69
(1) Purpose of air flow instruments	
(2) Types of air flow instruments	
(3) Operation of air flow instruments	
b. Using residential air conditioner trainer, air flow instruments, and workbook, balance the air flow to meet specifications in workbook. STS: 19j Meas: W, PC	(4/1.5) Day 69
(1) Purpose and application of air flow balancing	
(2) Principles of air flow balancing	
(3) Procedures for air flow balancing	

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SUPPORT MATERIALS AND GUIDANCE

Student Instructional Materials
SG 3ABR54530-VIII-1 thru -3, Typical Air Conditioning Equipment and Psychrometrics
WB 3ABR54530-VIII-2-P1, Determine Velocity and CFM of Air
WB 3ABR54530-VIII-2-P2, Balancing Air Conditioning Systems

Training Equipment
Trainer, Heating and Air Conditioning, Residential (2)
Trainer, Velometer (12)
Trainer, Anemometer (12)
Trainer, Manometer (12)

Training Methods
Discussion/Demonstration (3.5 hrs)
Performance (3.5 hrs)
CTT Assignment (2.5 hrs)

Multiple Instructor Requirements
Supervision (2)

Instructional Guidance
Place adequate emphasis on safety precautions while using refrigeration equipment. Outside Assignment: Day 69, direct students to review WBs VIII-2-P1 and P2.

MIR: Two instructors are needed for 3.5 hours during student performance in Day 69.

PLAN OF INSTRUCTION/LESSON PLAN PART I

NAME OF INSTRUCTOR	COURSE TITLE
	Refrigeration and Air Conditioning Specialist

BLOCK NUMBER	BLOCK TITLE
VIII	Air Conditioning

1 COURSE CONTENT	2 TIME
3. Psychrometrics	8 (5.5/2.5) Days 69 and 70
a. Using sling psychrometer, determine the wet bulb and dry bulb temperature of air within two degrees. STS: 19c Meas: W, PC (1) Purpose of sling psychrometer readings	(1/0.5) Day 69
b. Using psychrometric chart and workbook values, determine dew point temperature, relative humidity, specific humidity and heat content within two percent. STS: 19d(1), 19d(2), 19d(3) Meas: W, PC (1) Define psychrometrics (2) Physical properties (3) Lines and scales on the psychrometric chart (4) Simple psychrometric plots	(4.5/2) Day 70

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SUPPORT MATERIALS AND GUIDANCE

Student Instructional Materials
SG 3ABR54530-VIII-1 thru -3, Typical Air Conditioning Equipment and Psychrometrics
WB 3ABR54530-VIII-3-P1, Using Sling Psychrometer to Determine Dry Bulb and Wet Bulb Temperatures
WB 3ABR54530-VIII-3-P2, Using Psychrometric Chart to Determine the Properties of Air
HO 3ABR54530-VIII-1, Psychrometric Chart

Audio Visual Aids
Chart, Set, Psychrometrics
Transparencies, Set, Psychrometrics

Training Equipment
Trainer, Sling Psychrometer (12)

Training Methods
Discussion/Demonstration (2.5 hrs)
Performance (3 hrs)
CTT Assignment (2.5 hrs)

Instructional Guidance
Outside Assignment: Day 70, direct students to review WB VIII-3-P1 and P2

PLAN OF INSTRUCTION/LESSON PLAN PART I

NAME OF INSTRUCTOR	COURSE TITLE
	Refrigeration and Air Conditioning Specialist

BLOCK NUMBER	BLOCK TITLE
VIII	Air Conditioning

1. COURSE CONTENT	2. TIME
4. Measurement Test and Test Critique	1.5 (1.5/0) Day 70
5. Heat Pumps	4 (3/1) Day 71
a. Using workbook and heat pump, identify components and list their functions. STS: 15a(1), 19g, 19h Meas: W, PC	(1.5/0.5)
(1) Major components and their functions	
(2) Compressor motor safety controls	
(3) Principles of heat pump cycles	
b. Using heat pump and reversing valve diagrams, trace the flow of refrigerant through the cooling and heating cycles. STS: 19a, 19g, 19h Meas: W, PC	(1.5/0.5)
(1) Reversing valve operation	
(2) Refrigerant flow in heating and cooling cycles	

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SUPPORT MATERIALS AND GUIDANCE

Student Instructional Materials
SG 3ABR54530-VIII-5 thru -7, Heat Pumps, Package Air Conditioner and Direct Expansion Air Conditioning System
WB 3ABR54530-VIII-5-P1, Familiarization of Heat Pumps

Audio Visual Aids
Transparencies, Set, Heat Pumps
Prenarrated Slides: The Packaged Heat Pump

Training Equipment
Trainer, Heat Pump (12)
Trainer, Heat Pump Operation (12)

Training Methods
Discussion/Demonstration (1.5 hrs)
Performance (1.5 hrs)
CTT Assignment (1 hr)

Instructional Guidance
Outside Assignment: Day 71, direct students to preview WB VIII-3-P1 and P2.

PLAN OF INSTRUCTION/LESSON PLAN PART I

NAME OF INSTRUCTOR	COURSE TITLE
	Refrigeration and Air Conditioning Specialist

BLOCK NUMBER	BLOCK TITLE
VIII	Air Conditioning

1. COURSE CONTENT	2. TIME
6. Package Air Conditioner	4 (3/1) Day 71
a. Using the package air conditioner and workbook, identify components and list their functions. STS: 15a(1), 19g Meas: W, PC	(1.5/0.5)
(1) Purpose and applications of package air conditioners	
(2) Major components and their functions	
(3) Compressor motor safety controls	
b. Using the package air conditioner and workbook project, trace the flow of refrigerant, air and water through the system. STS: 19a, 19g, 19h Meas: W, PC	(1.5/0.5)
(1) Basic construction and air flow	
(2) Refrigerant system and condenser circuits	

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SUPPORT MATERIALS AND GUIDANCE

Student Instructional Materials
SG 3ABR54530-VIII-5 thru -7, Heat Pumps, Package Air Conditioner, and Direct Expansion Air Conditioning System
WB 3ABR54530-VIII-6-P1, Familiarization of the Package Air Conditioner

Audio Visual Aids
Transparencies, Set, Package Air Conditioner

Training Equipment
Trainer, Package Air Conditioner (12)

Training Methods
Discussion/Demonstration (1.5 hrs)
Performance (1.5 hrs)
CTT Assignment (1 hr)

Instructional Guidance
Place adequate emphasis on safety precautions around operating equipment.
Outside Assignment: Day 71, direct students to review WB VIII-6-P1.

PLAN OF INSTRUCTION/LESSON PLAN PART I

NAME OF INSTRUCTOR

Refrigeration and Air Conditioning Specialist

BLOCK NUMBER VIII

BLOCK TITLE Air Conditioning

1 COURSE CONTENT	2 TIME
7. Direct Expansion Air Conditioning Systems	30.5 (22.5/8) Days 72 thru 75
a. Using workbook and 25-ton trainer, locate, identify and state the function of safety controls and major components. STS: 15a(1), 19w(1) Meas: W (1) Major sections (2) Major components and their functions (3) Associated components and their functions (4) Safety controls	(6/2) Day 72
b. Using schematic, workbook and 25-ton trainer, locate operational and capacity controls, state their functions and adjust for proper operation. STS: 13a(6), 13a(7), 15c(1)(a), 15c(1)(b), 15c(2), 15c(3), 19w(2), 21h(4) Meas: W, PC (1) Temperature control system and its function (2) Humidity control system and its function (3) Control systems calibration and adjustments (4) Capacity control system and its function (5) Adjusting capacity controls to maintain proper operation	(6/2) Day 73

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PLAN OF INSTRUCTION/LESSON PLAN PART I (Continuation Sheet)

COURSE CONTENT

c. Using hygrothermograph, sling psychrometer, air flow instrument, psychrometric chart, and 25-ton trainer, perform capacity check to determine system efficiency as specified by instructor. STS: 5c, 5e, 6d(5), 19d(1), 19d(2), 19d(3), 19e, 19g, 19h, 19v(2), 19w(3), 21c(1), 21c(2), 21c(3), 21c(4), 21c(5), 21c(6), 21c (7) Meas: W, PC — (6/2) Day 74

(1) Pre-operational check and operational startup sequence and procedures

(2) Shutdown sequence and procedures

(3) Hygrothermograph

(4) Capacity check

(5) Probable causes and cures of reduced system capacity

d. Using diagnostic charts in study guide, multimeter and 25-ton trainer, troubleshoot and isolate malfunction to the smallest repairable or replaceable item. STS: 21d, 21e, 21f Meas, W, PC — (4.5/2) Day 75

(1) Troubleshooting

SUPPORT MATERIALS AND GUIDANCE

Student Instructional Materials

SG 3ABR54530-VIII-5 thru -7, Heat Pumps, Package Air Conditioner and Direct Expansion Air Conditioning Systems
WB 3ABR54530-VIII-7-P1, Major Components
WB 3ABR54530-VIII-7-P2, Compressor Electrical Control Circuits
WB 3ABR54530-VIII-7-P3, Fan Compressor Interlock Circuit
WB 3ABR54530-VIII-7-P4, Complete Temperature and Humidity Control Circuits
WB 3ABR54530-VIII-7-P5, Equipment Cooling Pneumatic Controls
WB 3ABR54530-VIII-7-P6, Identification and Adjustment of Cylinder Unloaders
WB 3ABR54530-VIII-7-P7, Preoperational Check of the 25-ton Trainer
WB 3ABR54530-VIII-7-P8, Operation of the 25-ton Trainer
WB 3ABR54530-VIII-7-P9, Determine Coil Capacity
WB 3ABR54530-VIII-7-P10, Determine Proper Operation
WB 3ABR54530-VIII-7-P11, Troubleshooting
HO 3ABR54530-VIII-1, Psychrometric Chart

PLAN OF INSTRUCTION/LESSON PLAN PART I (Continuation Sheet)

COURSE CONTENT

Audio Visual Aids
Chart, Set, Air Conditioning Systems
Transparencies, Set, Industrial Air Conditioning Systems

Training Equipment
Trainer, 25-Ton Air Conditioner (12)
Trainer, Sling Psychrometer (12)
Trainer, Hygrothermograph (6)
Trainer, Velometer (12)
Trainer, Reciprocating Cylinder Unloader (12)

Training Methods
Discussion/Demonstration (12 hrs)
Performance (10.5 hrs)
CTT Assignment (8 hrs)

Multiple Instructor Requirements
Safety, Supervision (2)

Instructional Guidance
Place adequate emphasis on safety precautions around operating equipment. Outside Assignment: Day 72, direct students to review WBS VIII-7-P1 thru P3; Day 73, P4 thru P6; Day 74, P7 thru P9; Day 75, P10 and P11.

MIR: Two instructors are needed for 9 hours during student performance (2.5 hours in Day 73, 3.5 hours in Day 74, and 3 hours in Day 75).

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PLAN OF INSTRUCTION/LESSON PLAN PART I

NAME OF INSTRUCTOR	COURSE TITLE Refrigeration and Air Conditioning Specialist
BLOCK NUMBER VIII	BLOCK TITLE Air Conditioning

1 COURSE CONTENT	2 TIME
8. Measurement Test and Test Critique	1.5 (1.5/0) Day 75
9. Indirect Expansion Air Conditioning Systems	36.5 (28.5/8) Days 76 thru 80
a. Using 100-ton trainer, maintain air handling system as outlined in workbook project. STS: 19d(1), 19d(2), 19d(3), 19t(3), 19v(3), 19v(4), 19w(1), 21h(1), 21h(2), 21h(3), 21h(4), 21h(5). Meas: W, PC (1) Types of air handlers (2) Air handler humidity control equipment (3) Psychrometrics (4) Air handler maintenance .	(5/1.5) Day 76
b. Using 100-ton trainer, trace flow, service and maintain secondary refrigerant system. STS: 19l, 19o, 19w(1). Meas: W, PC (1) Secondary refrigerant systems applications (2) Secondary refrigerant circuits (3) Service and maintenance of secondary refrigerant systems	(1/0.5) Day 76

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c. Using 100-ton centrifugal refrigeration machine and workbook, locate, identify and list the functions of components. STS: 12d, 13a(1)(c), 13a(3), 13a(4), 19k 19q. Meas: W, PC (6/2) Day 77

(1) Major components and their functions

d. Using workbook and chart, trace the centrifugal compressor lubrication system. STS: 13a(1)(c), 19h Meas: W, PC (2/0.5) Day 78

(1) Lubrication system components

(2) Oil circuit

(3) Servicing

e. Using workbook and chart, trace electrical safety control circuit. STS: 15a(1), 19p. Meas: W, PC (2/1) Day 78

(1) Safety controls and their functions

f. Using centrifugal trainer and equipment provided, connect the equipment for charging the system with refrigerant following prescribed step by step procedures. STS: 19m Meas: W, PC (2/0.5) Day 78

(1) Charging procedures

g. Using the 100-ton trainer, perform a preoperational check as outlined in the workbook. STS: 19e Meas: W, PC (1/0.5) Day 79

(1) Preoperational check

h. Using 100-ton trainer, operate the centrifugal units operational controls, transmitters, recorders and controllers to obtain optimum operational efficiency. STS: 19g, 19i, 19n, 19r, 19s Meas: W, PC (5/1.5) Day 79

(1) Starting, operating and stopping procedures

(2) System operating controls

COURSE CONTENT

i. Using diagnostic charts in study guide, and 100-ton trainer, troubleshoot and isolate to smallest repairable or replaceable item. STS: 10g(3), 10g(5), 15c(4), 21c(1), 21c(2), 21c(4), 21c(5), 21c(6), 21d, 21e, 21f. Meas: W, PC (4.5/0) Day 80

(1) Troubleshooting procedures

SUPPORT MATERIALS AND GUIDANCE

Student Instructional Materials
SG 3ABR54530-VIII-9, Indirect Expansion Air Conditioning System
WB 3ABR54530-VIII-9-P1, Using Psychrometric Chart to Determine the Properties of Mixed Air
WB 3ABR54530-VIII-9-P2, Operation and Maintenance of Fresh Air and Recirculating Air System
WB 3ABR54530-VIII-9-P3, Operation, Maintenance and Flow of Secondary Refrigerants
WB 3ABR54530-VIII-9-P4, Identification and Function of Major Components of Centrifugal Refrigeration Machine
WB 3ABR54530-VIII-9-P5, Tracing Flow of Primary Refrigerant
WB 3ABR54530-VIII-9-P6, Operating Principles of Purge Recovery Unit
WB 3ABR54530-VIII-9-P7, Servicing Centrifugal Compressor Lubrication System
WB 3ABR54530-VIII-9-P8, Centrifugal Unit Safety Controls
WB 3ABR54530-VIII-9-P9, Charging Procedures for Centrifugal Machine
WB 3ABR54530-VIII-9-P10, Preoperational Check and Operation of Centrifugal Machine
WB 3ABR54530-VIII-9-P11, Diagnose Troubles in the Centrifugal System
HO 3ABR54530-VIII-1, Psychrometric Chart

Audio Visual Aids
Chart, Set, Indirect Expansion Air Conditioning Systems
Transparencies, Set, Centrifugal Systems

Training Equipment
Trainer, 100-ton Air Conditioner (12)
Trainer, Purge Recovery Unit (12)

COURSE CONTENT

Training Methods
Discussion/Demonstration (15 hrs)
Performance (13.5 hrs)
CTT Assignment (8 hrs)

Multiple Instructor Requirements
Safety, Supervision (2)

Instructional Guidance
Place adequate emphasis on safety precautions around operating equipment. Outside Assignment: Day 76, direct students to review WBs VIII-9-P1 thru P3; Day 77, P4 thru P6; Day 78, P7 thru P9; Day 79, P10 and P11.

MIR: Two instructors are needed for 7 hours during student performance (4 hours in Day 79 and 3 hours in Day 80).

10. Related Training (identified in course chart)	2
11. Measurement Test and Test Critique	1.5 (1.5/0) Day 80

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PLAN OF INSTRUCTION/LESSON PLAN PART I

NAME OF INSTRUCTOR	Refrigeration and Air Conditioning Specialist
BLOCK NUMBER IX	Evaporative Cooling Systems, Communication Security, Publications, Civil Engineering Maintenance Mangement

1 COURSE CONTENT	2 TIME
1. Evaporative Cooling Systems	4 (4/0) Day 81
a. Using a schematic, identify the components and trace the flow of air and water through the evaporative cooler. STS: 19h Meas: W, PC	(1/0)
(1) Evaporative cooling fundamentals	
(2) Major components and their functions	
(3) Common service and maintenance problems	
b. Using the evaporative cooler, perform a preoperational check and operate the system. STS: 6d(3), 19e, 19f, 19g, 19h, 19t(3) Meas: W, PC	(3/0)
(1) Preoperational check and operate	
(2) Installation, service and maintenance procedures	

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SUPPORT MATERIALS AND GUIDANCE

Student Instructional Materials
SG 3ABR54530-IX-1 and 4, Evaporative Cooling Systems and Civil Engineering Maintenance Management
WB 3ABR54530-IX-1-P1, Major Components of Evaporative Coolers
WB 3ABR54530-IX-1-P2, Preoperation and Operation of Evaporative Coolers

Training Equipment
Trainer, Evaporative Cooler (12)
Trainer, Sling Psychrometer (12)

Training Methods
Discussion/Demonstration (1.5 hrs)
Performance (2.5 hrs)

Instructional Guidance
Place adequate emphasis on safety precautions around operating equipment.

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STUDY GUIDE 3ABR54530-VI-1 thru 3

Department of Civil Engineering Training

Refrigeration and Air-Conditioning Specialist

MULTIPLE REFRIGERATION SYSTEMS, EVAPORATIVE COOLING TOWERS AND WATER PUMPS

January 1975

SHEPPARD AIR FORCE BASE

11-8

75-5-43

Designed For ATC Course Use

DO NOT USE ON THE JOB

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REFRIGERATION AND AIR-CONDITIONING SPECIALIST

(Days 46-50)

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This supersedes SG 3ABR54530-VI-1 thru 2 and WB 3ABR54530-VI-1-P1 thru VI-3-P1 31 October 1973.
Copies of the superseded publication may be used until the supply is exhausted.

Dept of Civil Engineering Training
Sheppard AFB, Texas

SG 3ABR54530-VI-1
22 January 1975

MULTIPLE REFRIGERATION SYSTEMS

OBJECTIVE

To help you understand the reasons for installing multiple systems, and their classifications, applications, and installation requirements. To help you service, adjust and operate multiple refrigeration systems.

INTRODUCTION

The general term "multiple refrigeration systems" includes several different applications, each having its own purpose and temperature range. A multiple evaporator system is one in which two or more evaporators are operated from one compressor. A multiple compressor system is one in which one evaporator is operated from two or more compressors. These compressors may be either in series or in parallel.

MULTIPLE EVAPORATOR SYSTEMS

Multiple evaporator systems are installed for economy and to save space. It is cheaper to operate one compressor to control the temperature of two or more evaporators than to operate a compressor for each evaporator. Also, having one unit that has two or more temperature areas takes less space than a compressor for each temperature area.

Classifications of Multiple Evaporator Systems

Generally, multiple evaporator systems fall in one of two groups: First, where all evaporators have the same temperature. This is the simplest, although not the most common in use. Second, where each evaporator has a different temperature. This application is found in most multiple installations.

Applications of Multiple Evaporator Systems

Multiple evaporator units are often installed in restaurants, soda fountains, bars, meat and produce markets, and other places where the use of more than one refrigeration fixture is a necessity.

It must not be assumed that any two or more evaporators may be connected in multiple without regard to size, usage, humidity requirement, temperature, and similar conditions. There are some combinations that will not give satisfactory service and must be avoided. However, there is no concrete information that will apply in all cases, but there are certain conditions and rules that must be followed to insure a serviceable installation.

SINGLE TEMPERATURE EVAPORATOR SYSTEM

A multiple evaporator system may be operated as a single-temperature system. This means that all evaporators will have the same temperature range. In this case the needs of each evaporator will be controlled by a single-pressure control or thermostat. When all evaporators have been satisfied, the compressor will pull the pressure in the common suction line down to the cutout point of the pressure control. (Figure 1 illustrates a typical single temperature evaporator system.) The pressure control contacts then open stopping the operation of the system. As the pressure builds up in the evaporators, it also builds up in the common suction line. When the pressure in the common suction line reaches the "cut-in" setting on the pressure control, the pressure control contacts close and the compressor starts. When all evaporators are satisfied the compressor shuts off after the common suction line pressure drops to the cutout point set on the pressure control. This is a continuous process.

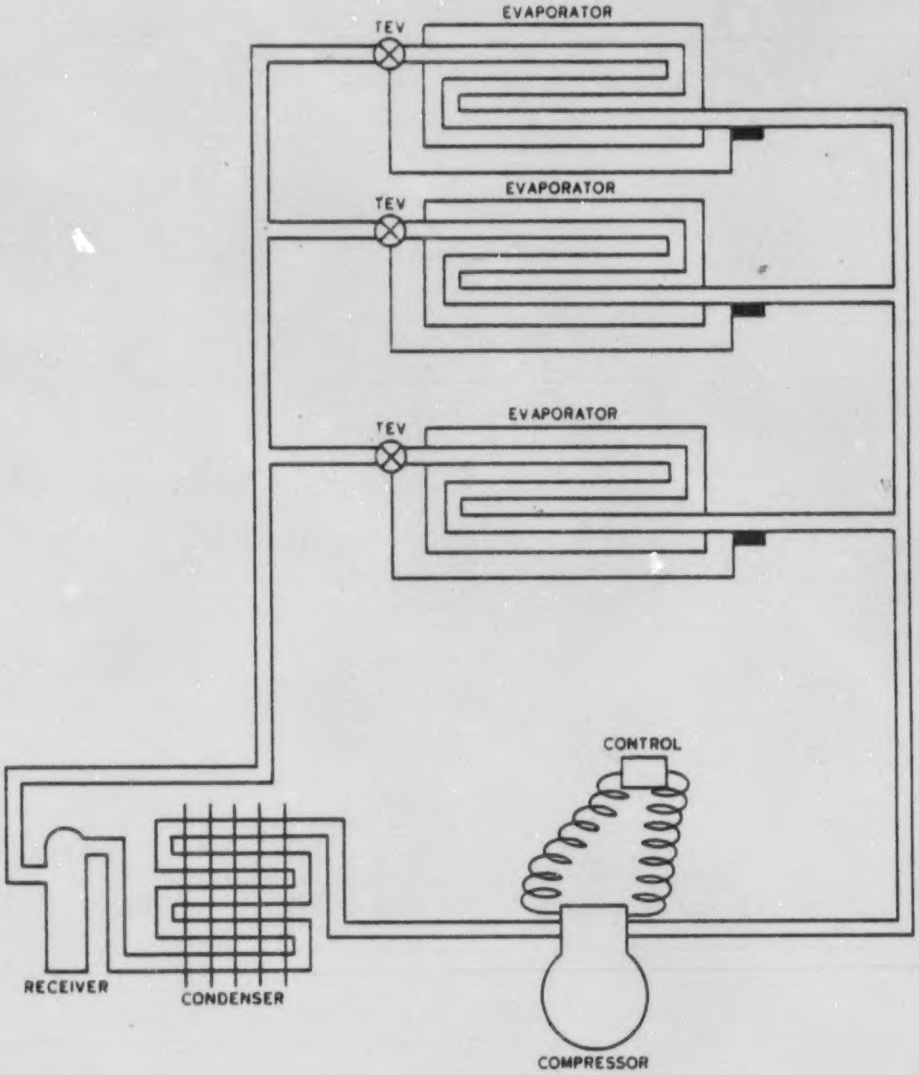
TEV
EVAPORATOR
TEV
EVAPORATOR
TEV
EVAPORATOR
CONTROL
RECEIVER
CONDENSER
COMPRESSOR

Figure 1. Single Temperature Evaporator System

Single Temperature Evaporator System Components

Following are the components of a single temperature evaporator system and the function of each component as in figure 1:

1. Compressor - Pressurizes and raises refrigerant temperature above ambient.
2. Condenser - Liquefies refrigerant.
3. Thermostatic Expansion Valve - Meters refrigerant to evaporator.
4. Evaporator - Refrigerant absorbs heat, vaporizes, and flows to compressor.
5. Receiver - Refrigerant reservoir.
6. Pressure Control - Starts and stops compressor according to the suction pressure increase and decrease.

Following are the components of a single temperature electrical system as in figure 2:

1. Pressure Control - Starts and stops current flow to the compressor motor.
2. Capacitor - Increases starting torque.
3. Thermal Overload - Protects the compressor against damage due to overheating.

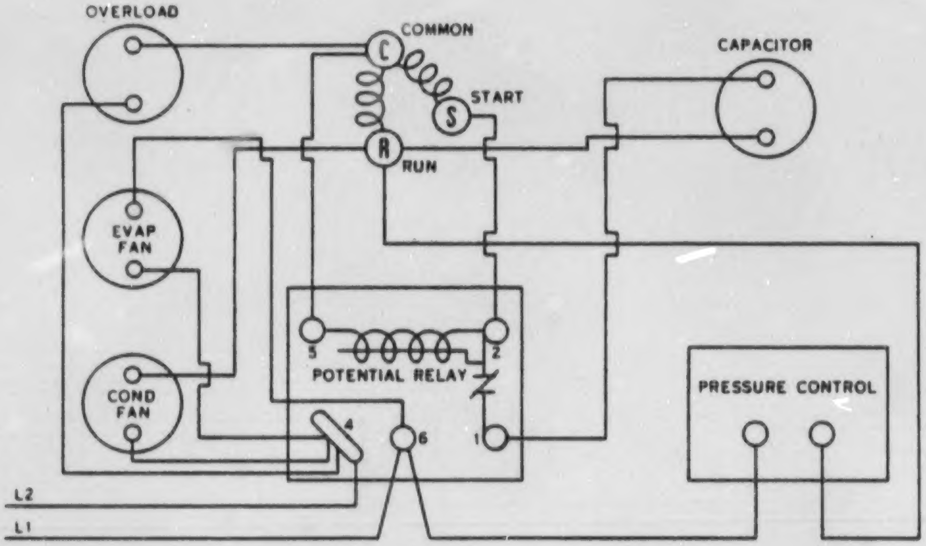
OVERLOAD
C
COMMON
S
START
R
RUN
CAPACITOR
EVAP FAN
COND FAN
5
2
POTENTIAL RELAY
4
6
1
PRESSURE CONTROL
L2
L1

Figure 2. Single Temperature Evaporator Electrical System

4. Starting Relay - Disconnects the start capacitor from the circuit.

5. Evaporator Fan - Forces air across the evaporator.

6. Condenser Fan - Forces air across the condenser.

7. Run Terminal - Connection to allow current to flow through the run winding.

8. Start Terminal - Connection to allow current to flow through the start winding.

9. Common Terminal - The Connection where current can leave both windings.

MULTITEMPERATURE EVAPORATOR SYSTEMS

The successful installation and operation of multiple systems requires the consideration of each application. The units give more efficient operation when installed close to each other. The following suggestions will be found useful as a guide. Due to the large number of possible multiple combinations it is impossible to give a specific set of rules and expect them to apply in all cases; therefore, it must be understood that there will be exceptions to the following rules:

1. The coldest evaporator must comprise more than half the total heat load. If the warmer evaporator comprised the largest part of the load, the condensing unit would be operating at the higher suction pressure most of the time. The condensing unit would not be able to bring the colder box down to the correct temperature.

2. The condensing unit must be selected to operate at the lowest suction pressure of the coldest evaporator. Since the colder evaporator constitutes the major part of the load, the compressor will be operating at that pressure most of the time. That is another case where it must be remembered that the efficiency of a compressor decreases as the suction pressure decreases.

3. Each evaporator must be selected for a given temperature and humidity. The selection is made just as if each evaporator is connected to its own compressor.

4. A special control is necessary where the temperature difference between the coldest and warmest evaporator is more than 5° F. This control must be either an evaporator pressure regulator or solenoid valve. If the evaporator temperature is the same, but one refrigerator is used more than the other, a control should be placed in the suction line of the refrigerator with the least usage.

5. A snap-action control must be used if defrosting on the "off cycle" is desired.

6. Connect the coldest evaporator closest to the compressor.

7. A check valve should be located in the suction line between the outlet of the evaporator and the common suction line on all but the warmest evaporator. Check valve will prevent warm refrigerant gas from flowing into a colder evaporator coil.

8. Thermostatic expansion valves should be used where direct expansion evaporators are installed.

9. The liquid and suction lines must be sized according to the need as if all evaporators were demanding refrigerant at the same time.

10. A multiple system will operate more efficiently when the temperature difference between the coldest and warmest temperature evaporators is not more than 25° F.

Control Valves For Multiple Units

When two or more evaporators are operated from the same compressor and the temperature difference is greater than 5° F, some type of control is necessary for the warmer evaporator. To accomplish this control, two types of control devices are used in various combinations, solenoid and evaporator pressure regulating valves.

SOLENOID VALVE MULTITEMPERATURE SYSTEM

The refrigerant flow in this system is controlled by solenoid valves. The solenoid is a simple electromagnet consisting of a coil of wire which, when energized by an electric current, produces a magnetic field that will attract ferrous metals such as iron and alloys. An armature (plunger) is placed in a sealed housing with the coil placed around the housing. Each valve is controlled by a thermostat. Each valve is wired in series with its thermostat but in parallel with the other valves and thermostats.

Types of Solenoid Valves

There are two types of solenoid valves, direct acting and pilot operated. They are located in the liquid lines, before the thermostatic expansion valves or in the suction lines. In the direct acting, the solenoid coil opens the main port directly by lifting the valve off the seat.

The pilot operated solenoid is used on large systems. In this valve the plunger opens a pilot port which allows pressure on top of a piston to be released through the pilot port. This creates a pressure unbalance across the piston. The pressure is now greater under the piston than above and the piston moves upward opening a main port. To close the valve the piston closes the pilot port, equalizes the pressure and the main valve closes.

Principle of Operation

Assume that all evaporators are warm and the compressor is operating. As the temperature of each evaporator is reached, its thermostat stops current flowing to the solenoid coil and the valve closes. If this valve is located in the liquid line it will stop refrigerant flow, but the compressor continues to operate. The pressure in each evaporator continues to go down, but very little refrigeration is taking place because no liquid is entering. When all valves are closed, the compressor pulls the pressure in the suction line down to the cutout point; and the pressure control stops the system.

When the temperature of either evaporator increases to the cut-in setting, its thermostat current is directed to the valve causing it to open so refrigerant can flow into the evaporator. (See figure 3 for a typical system.) When the evaporator pressure causes suction pressure to rise to the cut-in point on the pressure control, the compressor starts. After the evaporator is satisfied, the valve closes, the suction line pressure drops to the low-pressure motor control cutout point, and the compressor stops.

If the system is equipped with solenoid valves in the suction line, the valves will close as the evaporators are satisfied. There is very little cooling since there is no refrigerant movement; however the compressor operates until the suction line pressure drops to the cutout point and the low pressure motor control stops the compressor. Usually an accumulator is placed in the suction line near the compressor to insure that no liquid refrigerant enters the compressor when any solenoid valve first opens. See figure 3A.

Check valves allowing free flow in one direction and none in the other are installed in the suction line of all evaporators except the warmest. When the solenoid valve opens, the high pressure vapor in the warmer evaporator would back up into the colder ones if no means were provided to prevent it. This would cause a warming of the colder evaporators resulting in a loss of efficiency. Then they would all call for refrigerant.

There are several important factors that must be considered when using solenoid valves in multiple systems. These are receiver size, defrosting of the coil and low pressure motor control. The receiver must be large enough to hold the entire refrigerant charge in the system. As each liquid line solenoid valve closes, the refrigerant is pumped out of the evaporator and returned to the receiver. When the solenoid valve closes, the pressure in the evaporator will continue to drop. This will keep the evaporator from warming up enough for the coil to defrost. The low pressure control should be set to cut in and out for the pressures of the coldest evaporator. It will then operate for the warmer evaporators.

Solenoid Valve Selection

The type of control application requires definite information concerning the valve selection. The fluid to be controlled, capacity needed, maximum working pressure, maximum operating pressure differential (MOPD), and electrical characteristics are factors that must be known.

The selection of a valve depends on whether it is used on liquid or gas, as the specific volume of a gas varies with pressure and temperature. The capacity of a valve is given in tons of refrigeration with a 2-4 psi pressure drop across the valve for liquid and 1 psi for gas.

The MOPD is the pressure against which the solenoid will operate the valve. This pressure is measured between the inlet and outlet of the valve when it is closed. The valve rating must be equal to or better than the maximum operating pressure of the system. The electrical characteristics include voltage, phasing, and cycles.

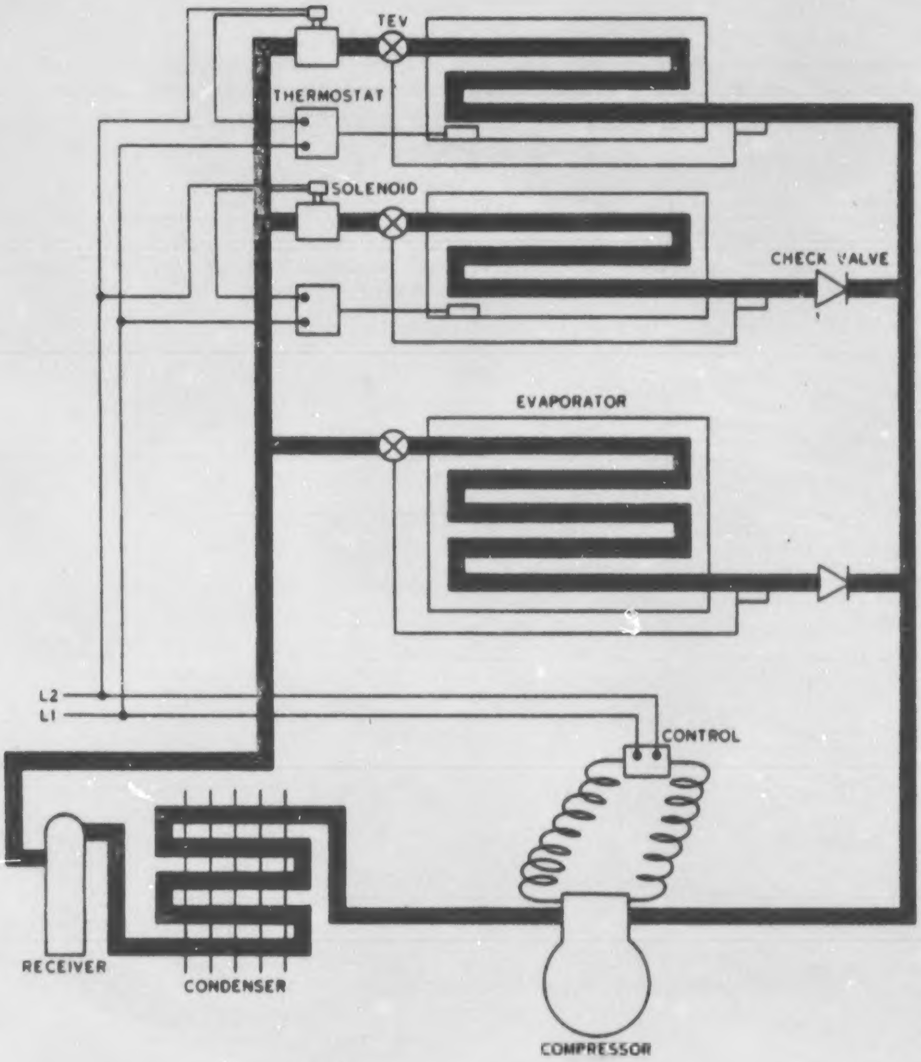
TEV
THERMOSTAT
SOLENOID
CHECK VALVE
EVAPORATOR
L2
L1
CONTROL
RECEIVER
CONDENSER
COMPRESSOR

Figure 3. Solenoid Valve Multitemperature System (Liquid Line)

60

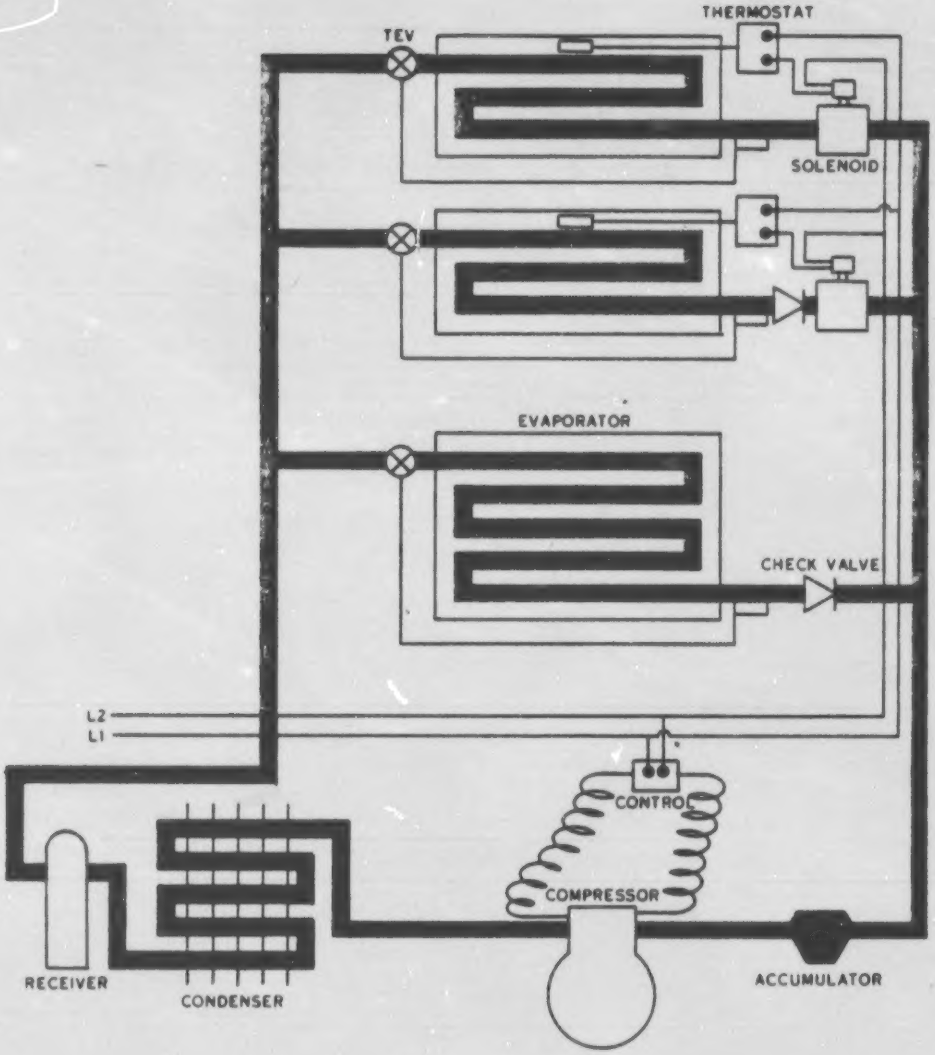
THERMOSTAT
TEV
SOLENOID
EVAPORATOR
CHECK VALVE
L2
L1
CONTROL
COMPRESSOR
RECEIVER
CONDENSER
ACCUMULATOR

Figure 3A. Solenoid Valve Multitemperature System (Suction Line)

Installation of Solenoid Valves

Most solenoid valves are closed by gravity. As a result they must operate in a vertical position and must be placed in a horizontal line. They can be placed in either the refrigerated space or in normal ambient temperature areas. A strainer should be placed in the line ahead of the valve. The valves are marked with direction of flow and should be installed in the right direction.

When installing a valve with sweat type connections, the valve should be taken apart and the body wrapped in a wet rag so that the valve will not be warped. However you should not let moisture get inside the valve.

Solenoid Valve Malfunctions

Should a solenoid valve fail to function properly, the following service hints indicate some of the probable causes of failure and suggestions for correcting the trouble.

When the valve fails to open, check for:

1. A broken wire to the coil. Isolate the solenoid by disconnecting the leads. Check for continuity through the coil. If the resistance is infinity, replace the coil.

2. System operating pressure too high. Check actual pressure differential across valve against nameplate MOPD rating. If the actual differential exceeds the nameplate rating, a valve with a higher MOPD rating must be used.

3. Valve body or internal parts warped due to excessive brazing temperatures or excessive wrench torque. Replace damaged valve or component parts as required. When threading pipe into the valve, do not apply pressure either by hand or by wrench against coil housing or enclosed tube. Instead, apply wrench on flats provided on valve body for this purpose.

4. Dirt or sludge causing valve to stick. Dismantle valve and completely clean interior and component parts. Install a strainer with a mesh adequate to prevent foreign material from reaching valve.

5. Low voltage. The voltage applied to the solenoid valve coil must be at least 85 percent of the rated nameplate voltage. If voltage is found to be lower than that value, the cause of the voltage drop must be determined and corrected. Common causes of voltage drop are undersized supply wires, other load connected in series with solenoid coil, loose connections, and faulty control switches.

6. Coil burnout. Excessive voltage is the most common cause of solenoid coil burnout. Solenoid coils should not be subjected to a voltage greater than 10 percent above the rated nameplate voltage. Prolonged exposure to excessive ambient temperatures can also cause coil burnout. If the valve cannot be relocated in a space with a more reasonable temperature, the use of a special high temperature coil is advisable.

When the valve fails to close, check for:

1. Valve body or internal parts warped due to excessive brazing temperatures or excessive wrench torque. Replace damaged valve or components parts as required.

2. Dirt or sludge causing valve to stick open. Dismantle valve and clean all parts. Install a strainer to prevent a similar occurrence.

3. Electrical circuit closed because of faulty switch or relay contacts.

4. Congealed oil causing valve to stick. Refrigerant oil should be of the type for the temperature range of the system. This is especially true on low-temperature applications where only a good grade of low temperature oil should be used.

SOLENOID VALVE MULTITEMPERATURE ELECTRICAL SYSTEM. As you can see in figure 4, the electrical system for the solenoid valve multitemperature system is almost identical to the single temperature system. The only difference is the addition of a terminal block, two thermostats and two solenoids. The thermostats control the temperatures in each of the warmer refrigerated spaces. The thermostats do this by energizing and deenergizing the solenoids. The solenoid valves control the refrigerant flow to the evaporators of these warmer boxes. The refrigerant flow to the coldest evaporator is controlled solely by the DPMC.

EVAPORATOR PRESSURE REGULATOR MULTITEMPERATURE SYSTEM

The refrigerant flow is controlled by evaporator pressure regulators in this system. The evaporator pressure regulator (EPR valve) is the oldest and perhaps best known of these suction line controls. Its sole function is to prevent the evaporator pressure from falling below a predetermined pressure for which the regulator has been set. The EPR maintains a constant pressure in the evaporator coil. It may be used on a multiple system to maintain certain minimum pressures on individual evaporators.

Types of Evaporator Pressure Regulator Valves

The type of EPR valves are direct and pilot operated. Following are specific types in each.

1. Direct acting. Metering EPRs operate as a device on the suction side of the evaporator. It modulates, opens, and closes when the pressure in the evaporator varies only a fraction of a pound. The control element can be either a diaphragm or bellows. Figure 5 illustrates a system using this type of EPR valve. Snap-action type which is designed so that a decided rise in pressure is made in the coil before the valve will open. This type is used on an evaporator where defrost on the off cycle is desired. It is either fully open or closed. It does not modulate. Thermostatic EPRs have a thermobulb that is attached to the evaporator, and the operation of the control is by the temperature of the evaporator on the power element. This type can be either modulating or snap-action.

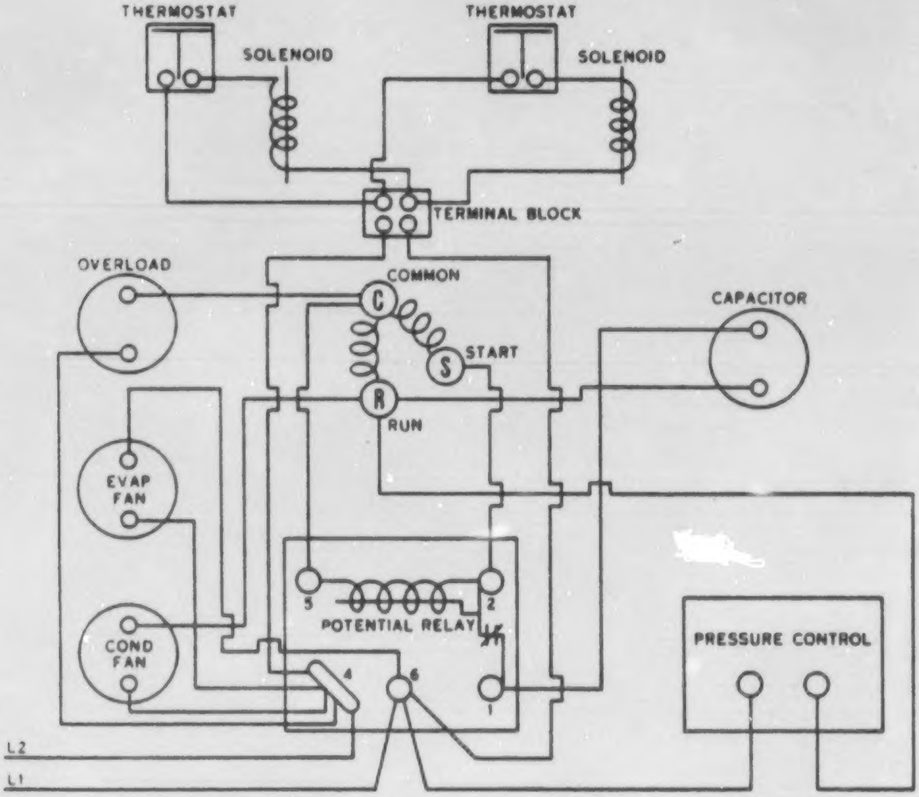
THERMOSTAT
SOLENOID
THERMOSTAT
SOLENOID
TERMINAL BLOCK
OVERLOAD
COMMON
C
S
START
R
RUN
CAPACITOR
EVAP FAN
COND FAN
5
2
POTENTIAL RELAY
4
6
1
PRESSURE CONTROL
L2
L1

Figure 4. Solenoid Valve Multitemperature System

2. Pilot operated. This type is used on small or large systems. When the pressure in the evaporator rises above the pressure setting of the pilot, the pilot valve opens admitting pressure to the top of the main piston. The piston moves down, opening the main port allowing the evaporator pressure to drop back to the original setting. When the pressure drops below the pilot pressure setting, the pilot closes. The main spring closes the main valve as the pressure on top of the main valve decreases. Thereby evaporator pressure does not fall below the pressure setting of the pilot. The two types of pilot controlled valves are internal and external. The internal type receives its source of pressure from the regulator inlet connection. The external pilot type receives its source of pressure for pilot operation from a line connected to the surge drum or suction header on the evaporator pressure regulator.

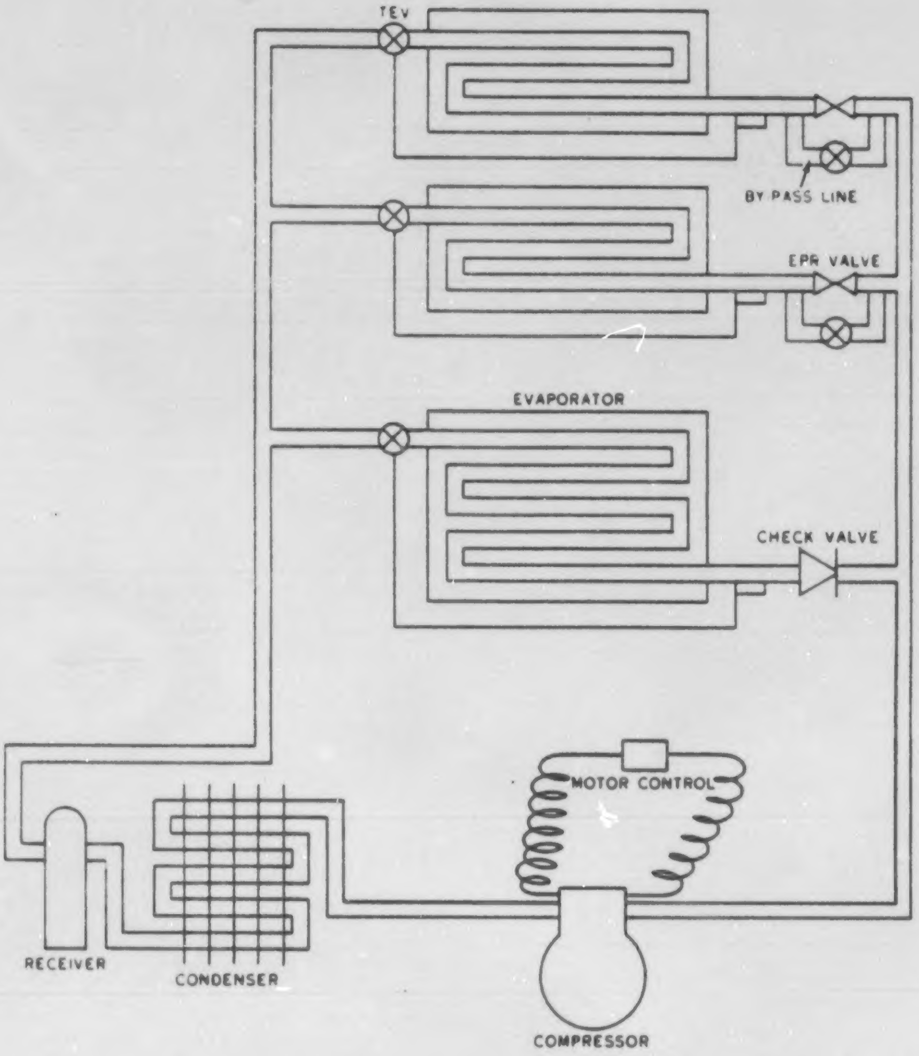
TEV
BY PASS LINE
EPR VALVE
EVAPORATOR
CHECK VALVE
MOTOR CONTROL
RECEIVER
CONDENSER
COMPRESSOR

Figure 5. Evaporator Pressure Regulator Multitemperature System

Operation of the EPR

When the cutout temperature of an evaporator is determined, the EPR valve is adjusted. As the compressor operates the pressure in the evaporator is lowered. When it reaches the cutout point of the evaporator the valve will close. This stops the flow of refrigerant through this evaporator. As the temperature and pressure rises in the evaporator they rise in the valve forcing the valve off its seat. This will hold the evaporator pressure constant because of the gradual movement of refrigerant. If the gradual flow of refrigerant is sufficient to make the pressure in the common suction line increase to the cut-in point of the motor control, the compressor will operate. This will pull the pressure down to the cutout point. If there is a rapid evaporator pressure increase because of the addition of a high heat load, the valve will open all the way. This directs the evaporator pressure to the common suction line where it is pulled down to the cutout point of the compressor. The valve will close when the evaporator is cold enough.

EPR Valve Selection

These valves can be selected from manufacturer's catalogs. These catalogs contain valve capacity tables. Each valve is listed according to its capacity in tons of refrigeration. Along with the capacity it is also listed for pressure drop across the valve. This means that refrigerant enters the valve at one pressure and leaves the valve at a lower pressure. The difference between the entering and leaving pressures is the amount of pressure drop across the valve.

The EPR valve should be selected to operate at the lowest pressure of the evaporator. It may also be selected for the type of refrigerant used in the system. Be sure to select a valve with the correct fittings for the system.

Installation Procedures

The regulators should be installed in the outlets of the warmer evaporators. The valves will have either sweat, flare, or flanged fittings. When installing a valve with sweat fittings, remove all internal parts and wrap the remaining parts of the valve with a wet cloth. This precaution prevents damage to the valve due to overheating while soldering. The EPR valve may be installed in any position with the exception of the thermostatic which must be installed vertically. There should be a bypass line with a hand valve installed around the EPR valve. This is to aid in pump down of the system without disturbing the valve setting or allowing the valve to interrupt refrigerant flow.

Evaporator Pressure Regulator Malfunctions

If an EPR valve fails to function properly, the following service hints indicate some of the possible reasons for failure alongwithproper steps to place the regulator back in operation:

1. A regulator stuck in the closed position is indicated by a rise in evaporator pressure and temperature. Dirt or foreign material in the regulator may be causing the piston to stick or bind. Take the valve apart and clean the internal parts thoroughly.

2. A regulator stuck in the open position is indicated by a low evaporator temperature and pressure. Dirt or foreign material in the regulator may cause the valve to remain open. Clean internal parts. If the parts are worn--replace the EPR valve.

3. A leaking regulator is indicated by a suction pressure buildup. The valve seat is most likely worn or eroded; and, should this be the case, the valve should be removed and replaced with a new like item.

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MULTIPLE COMPRESSOR SYSTEMS

A multiple compressor system is two or more compressors operating on one evaporator. The compressors may be connected in parallel or in series. Figure 6 illustrates a typical multiple compressor that is piped in parallel. This unit is used to maintain a refrigerated space having a high or varying heat load. It can be used in air conditioning, refrigerated warehouses or walk-in boxes. Multiple compressor systems are also used to obtain ultralow temperatures.

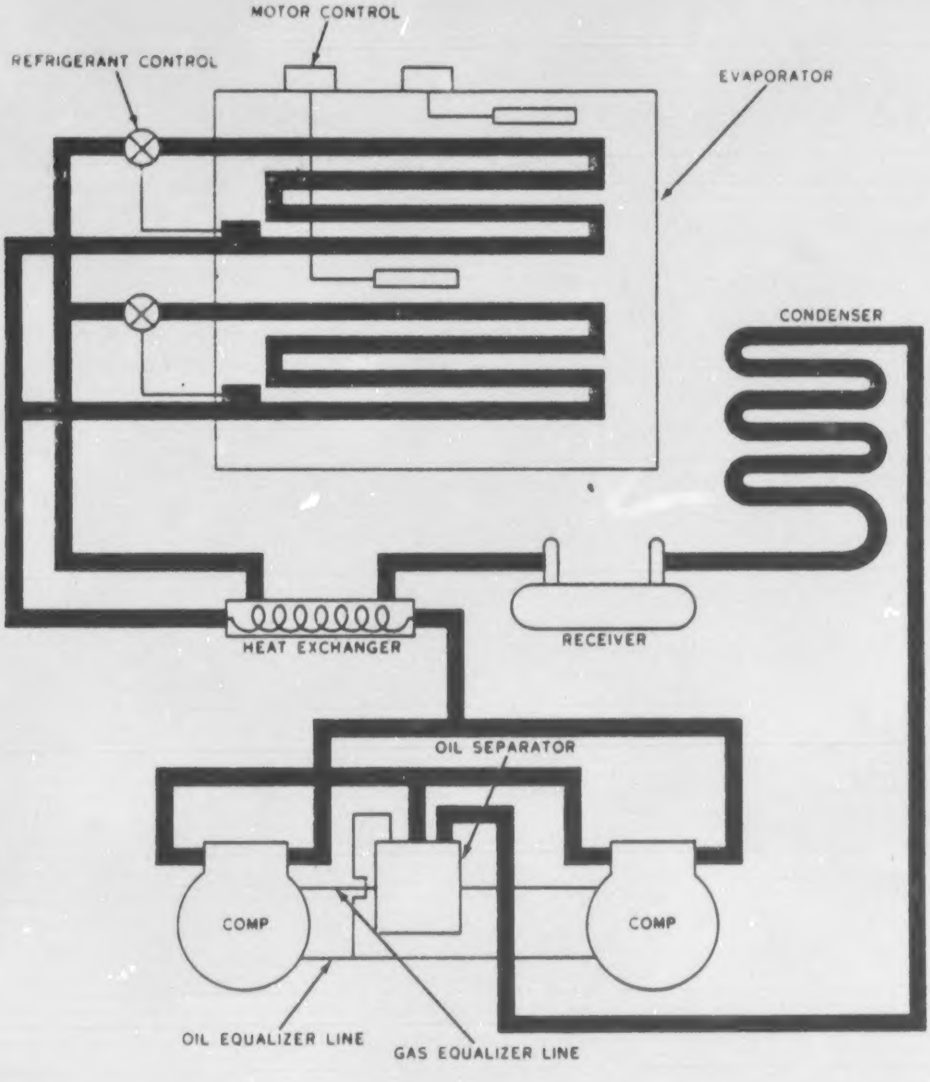
MOTOR CONTROL
REFRIGERANT CONTROL
EVAPORATOR
CONDENSER
RECEIVER
HEAT EXCHANGER
OIL SEPARATOR
COMP
COMP
OIL EQUALIZER LINE
GAS EQUALIZER LINE

Figure 6. Multiple Compressor System Piped in Parallel

Multiple Compressors Piped in Parallel

Operating a refrigeration system with several compressors and one evaporator is not new. It has always been a common practice to use two, three, or even four compressors on one evaporator in ice plants. As an example, a 100-ton ice plant may use four compressors. In the winter, three of these units could be shut off and only one operated. Then in the spring as the weather warms up and the demand for ice increases, another unit can be started. In the hot summer with the plant operating at maximum output all four compressors would be operating.

Advantages

Here are some advantages to be gained by using multiple compressor units on one evaporator space:

1. Partial operation in case of failure of one unit.

2. Economy of operation at low loads.

3. Control of refrigeration effect.

There are many warehouses in the Air Force that use multiple compressor systems. These warehouses contain thousands of dollars worth of perishable commodities. In the event one compressor fails, the other can maintain the temperature low enough to prevent spoilage until the malfunctioning unit can be repaired.

The second advantage is the economy of operation. An air-conditioned theater is a good example. Assume the maximum load is 75 tons, and the system is equipped with three 25-ton units. On a hot Sunday afternoon with the theater filled to capacity, all three units would be operating. However, on a cool weekday with only a few customers, the load may be 25 tons or less requiring the operation of only one unit with a savings in power cost and equipment usage. A check of summer operating time may indicate that the third unit was required less than 1/10th of the time.

The refrigeration effect can be maintained in this theater regardless of the heat load. One 25-ton compressor cools the theater on a cool weekday. As the heat load increases the second compressor cycles. At maximum load the third compressor cycles.

Disadvantages

1. The initial cost of two small condensing units is more than for one big unit that equals the capacity of two small ones. It is cheaper to install one big unit instead of two small ones.

2. There will be a small difference in crankcase pressure. The suction pressure must be the same in each crankcase. If the pressures are not equal the oil will collect in the compressor with the lowest pressure. This will cause the other compressor to fail due to a lack of oil. This difference is corrected by using equalizing lines. Gas and oil equalizer lines are connected to the crankcase of each compressor. The gas equalizer line must be installed above the maximum oil level. The oil equalizer line must be installed below the minimum oil level.

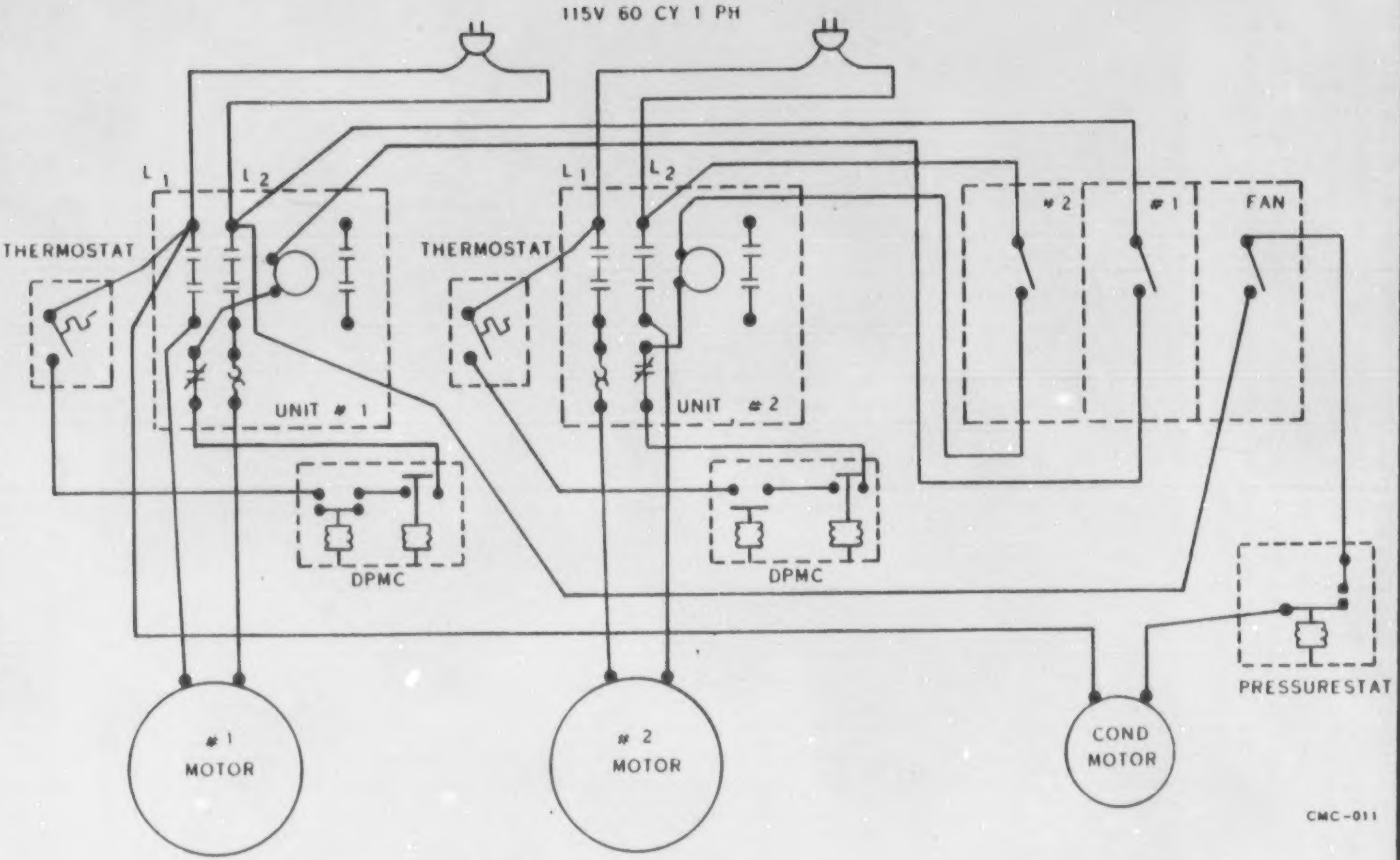
115V 60 CY 1 PH
L1
L2
THERMOSTAT
UNIT # 1
DPMC
L1
L2
THERMOSTAT
UNIT # 2
DPMC
# 2
# 1
FAN
PRESSURESTAT
# 1 MOTOR
# 2 MOTOR
COND MOTOR
CMC-011

Figure 7. Electrical Components for Multiple Compressors in Parallel

TEMPERATURE RANGES

The four temperature ranges pertaining to refrigeration are:

High:	32° F and above
Medium:	32° F to 0°
Low:	0° F to -40° F
Ultralow:	-40° F and below

There are problems in each range that are not found in other ranges. In the high temperature range there is the problem of condensation, dehumidification and condensate water disposal. Medium temperature range gives us the problem of automatic defrost systems. Automatic defrost systems are not needed in high temperature work and cannot be used on ultralow temperature systems. To heat the evaporator coil of an ultralow system above 32° for defrost purposes would greatly decrease the efficiency of the system. In low temperature refrigeration work, the effectiveness of the compressor decreases. This is due to the fact that the efficiency of the condensing unit decreases as the suction pressure decreases.

Ultralow temperature refrigeration systems present several problems. The problems become more critical as the temperature lowers. Following are some of the common problems encountered in the ultralow temperature work: insulation requirements, refrigerant requirements, refrigerant controls, lubrication requirements, and loss of compressor efficiency due to volumetric deficiency.

ULTRALOW TEMPERATURE SYSTEMS

The use of ultralow temperature refrigeration has increased tremendously in the past few years. It is used for food processing (freeze-dry) and operational testing of various instruments, such as electronic equipment. The Air Force uses ultralow temperature refrigeration for testing of instruments and simulated flight conditions.

Insulation Requirements

As the difference between room temperature and box temperature increases, the temperature difference is often 200° F or more. This requires 10 to 12 inches of insulation. If the box is expected to hold a low temperature at all times, it is best to use a high-thermal capacity insulation such as cork or foam glass. However, if you expect to simulate flight conditions, a high temperature for one period of time and a low temperature for the next, it is necessary to use an insulating material with a low-thermal capacity such as "Ferrotherm." This is a number of thin sheets of steel with air or Santocel (silica aerogel) filling the spaces between each sheet. By using Ferrotherm it is possible to produce temperatures from 75° F above to 75° F below in less than one hour.

Refrigerant Requirements

There are four refrigerants that work satisfactorily in ultralow systems. These are R-22, R-13, R-13B1 and R-502. R-22 will produce a temperature of -40° F at atmospheric pressure. At 23 inches of vacuum it boils at -90° F. This refrigerant is used very often in meat storage cabinets and in the first stage of the cascade system. R-13 is the best refrigerant obtainable for use in the first stage of a cascade system. It will produce a temperature of -110° at atmospheric pressure, but the high side pressure is very critical. The high side pressure is 100 psig with a temperature of -25° F. This shows that when using R-13, it is necessary to cool the condenser with refrigerant. R-13 has a pressure of 520 psig at 80° F which is its critical temperature.

Refrigerants such as ammonia, sulphur dioxide, and methyl chloride cannot be used in ultralow temperature systems. The specific volume of ammonia and methyl chloride is too high, and sulphur dioxide will freeze to a solid at -98° F or less. R-12 has been used in some systems to maintain a temperature of -100° F. Its specific volume and low evaporator pressure (27 inches of vacuum at -100° F) makes it less acceptable than either R-22, R-13, R-13B1 or R-502.

All low temperature refrigerants have very high head pressures. For this reason pressure relief valves must be installed in each system using these refrigerants.

Refrigerant Controls

Ordinary expansion valves are not satisfactory for use in ultralow refrigeration installations. The excessive superheating at the bulb location makes them unacceptable for use in systems with a temperature less than -40° F.

Expansion valves for ultralow temperature systems are not available through normal supply channels. Various manufacturers will furnish cross-charged valves for ultralow temperature work. Each valve is engineered and designed for a specific load, temperature range, and application.

Lubrication Requirements

All halocarbon refrigerants have a tendency to remove the wax from the oil in the system. As the temperature decreases, the tendency of the wax to separate from the oil increases. When the wax separates from the oil, it will "plug up" the needle in the expansion valve giving an indication of a "frozen" expansion valve.

Oil must be processed especially for ultralow temperatures. It must have a very low wax content and possess lubricating properties at very low temperatures. The use of an oil separator to keep the oil out of the low temperature evaporator will help minimize the lubrication problems.

Volumetric Deficiency

There must be some space between the top of the cylinder and the piston head when the piston is at top dead center. This space is known as "mechanical clearance." The gas left in this space after the compression stroke is equal to the head pressure. As the piston starts down, this pressure reduces until it is less than the low side. As soon as the pressure in the cylinder becomes less than the low side, the vapor from the low side flows into the cylinder. The lower the suction pressure the farther downward the piston must travel before vapor is emitted into the cylinder. If R-12 is used to maintain an evaporator temperature of -80° F, the low side would be 24 inches of vacuum. If the high side pressure is 100 psig and unless we use a very long cylinder, the pressure in the cylinder will never reduce below 24 inches of vacuum. It is apparent that it is impossible to get -80° F temperature using R-12 and a single-stage compressor. The compression ratio would be over 30:1.

This problem is overcome by using one of two ultralow temperature systems.

TYPES OF ULTRALOW TEMPERATURE SYSTEMS

Direct Compounding

In this system the compressors are connected in series. One compressor will compress the refrigerant and discharge it into the suction of the other. The pressure of the refrigerant is increased by the second compressor and discharged into the water-cooled condenser. The same refrigerant is used throughout the system.

Cascading

This system is composed of two complete refrigeration units connected by an interstage heat exchanger. This heat exchanger is the condenser for one unit and the evaporator for the other. The evaporator of the high-pressure unit removes heat from the condenser of the unit that reaches ultralow temperatures. Two different refrigerants must be used in this system.

DIRECT COMPOUNDING

A simple direct compounding system consists of two or more compressors in series. This installation gives satisfactory results, but the addition of intercoolers and subcoolers will increase the system's efficiency without increasing the cost of operation. Of several arrangements used for direct compounding, the two most common are the intercooler and subcooler systems.

Intercooler System

The intercooler system is illustrated in figure 8. The first-stage compressor draws the vapor from the evaporator through the heat exchanger. The vapor is then compressed and discharged to an intercooler where the superheat that was added by the first stage compressor is removed. You will note that the first compressor has reduced the volume of gas approximately one-half, resulting in the requirement for the second compressor to be only one-half as large as the first compressor.

The cooled vapor from the intercooler is drawn into the suction side of the second stage compressor where it is compressed and discharged to the condenser. The size of the intercooler is critical. If the vapor is cooled enough in the intercooler, it will condense into a liquid and cause a liquid lock in the second stage compressor. The liquid refrigerant leaves the condenser, passes through the heat exchanger and then back into the evaporator, completing the cycle. The use of heat exchangers to reduce the temperature of the liquid before it enters the evaporator is an absolute necessity in this type of refrigeration system.

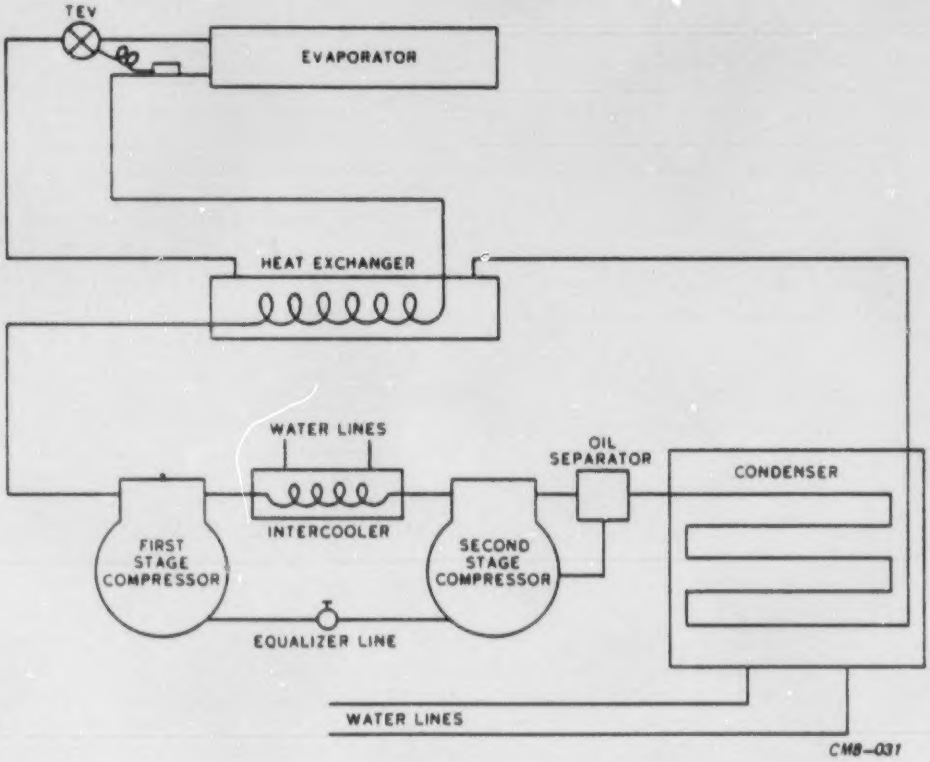
TEV
EVAPORATOR
HEAT EXCHANGER
WATER LINES
OIL SEPARATOR
CONDENSER
INTERCOOLER
FIRST STAGE COMPRESSOR
SECOND STAGE COMPRESSOR
EQUALIZER LINE
WATER LINES
CM8-031

Figure 8. Compound System with Intercooler

Subcooler System

The subcooler type system is shown in figure 9. This system operates on the principle that the cooler the refrigerant when it enters the evaporator, the less flash gas will be formed. The purpose of the subcooler is to cool the hot liquid refrigerant before it goes into the evaporator. Starting at the condenser, the hot liquid refrigerant passes through line C where part of it goes into line B and into the subcooler to be cooled. The rest of the liquid goes down to line A to the expansion valve and into the subcooler coil. Here it evaporates and cools the liquid refrigerant in the subcooler. The second stage compressor moves the vapor from the subcooler coil, compresses it, and returns it to the condenser. The subcooled liquid refrigerant leaves the subcooler, goes through the expansion valve and into the evaporator where it boils and turns into a vapor. The first-stage compressor removes this vapor, compresses it, and discharges it into the second compressor. The second-stage compressor completes the compression and discharges the hot vapor to the condenser, completing the cycle. Very often this type system uses a V-type compressor with the first-stage compressor twice as large as the second. This type compressor requires only one motor and eliminates the problem of oil level equalizing.

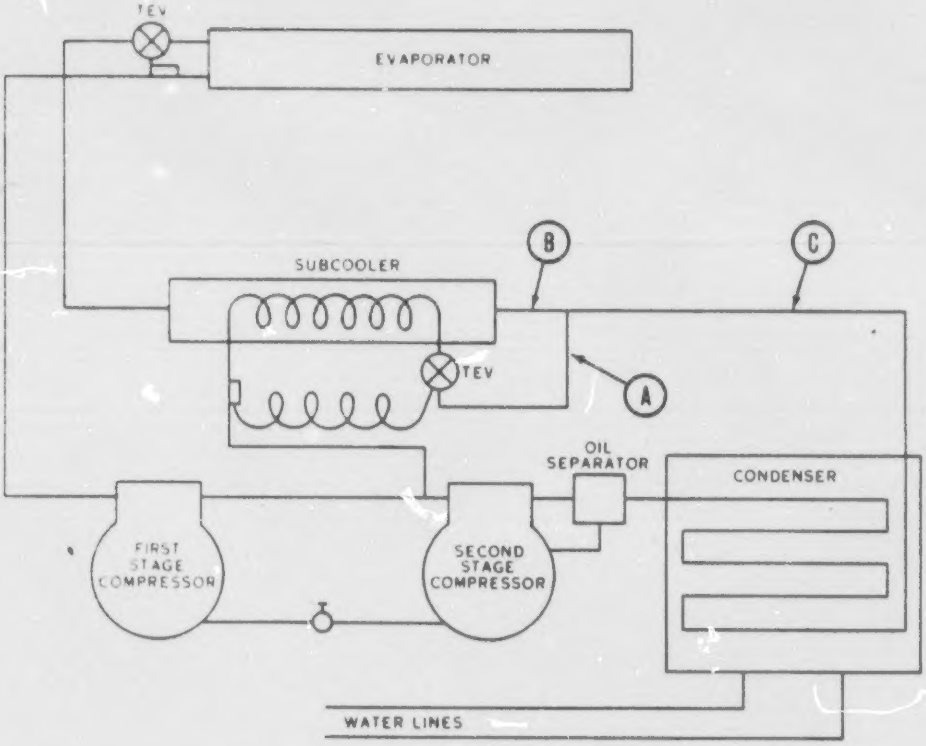

Figure 9. Subcooler System

CASCADE SYSTEMS

The word cascade means "steps." It is more often used in referring to a type of waterfall. The water falls from a high level down to the bottom. Falls of this type might be considered two separate waterfalls. This is the same with a cascade refrigeration system. It is two or three independent refrigeration systems operating in conjunction with each other but at different temperature levels. The connecting point of the systems is a condenser-evaporator. This unit is the condenser for the first system and the evaporator for the second.

There are two completely independent refrigeration cycles in this system. It has two main advantages over the direct compounding system; (1) there is no problem of oil equalizing, and (2) a different refrigerant is used in each system. R-13 is usually used in the low temperature cycle and R-12 in the high temperature cycle.

Elementary Cascade System

An elementary cascade system is shown in figure 10. The first stage compressor removes the vapor from the low-temperature evaporator, compresses it, and discharges it into the condenser-evaporator. Here it is cooled and condensed by the second-stage system. The liquid refrigerant goes through the expansion valve into the evaporator completing the cycle for the first stage system. Starting at the condenser of the second-stage system, the liquid goes through the expansion valve into the coil in the condenser-evaporator. Here it turns to a vapor from the heat of the first stage system. The second stage compressor removes the vapor from the coil in the condenser-evaporator, compresses it, and discharges it into the condenser, completing the second stage cycle.

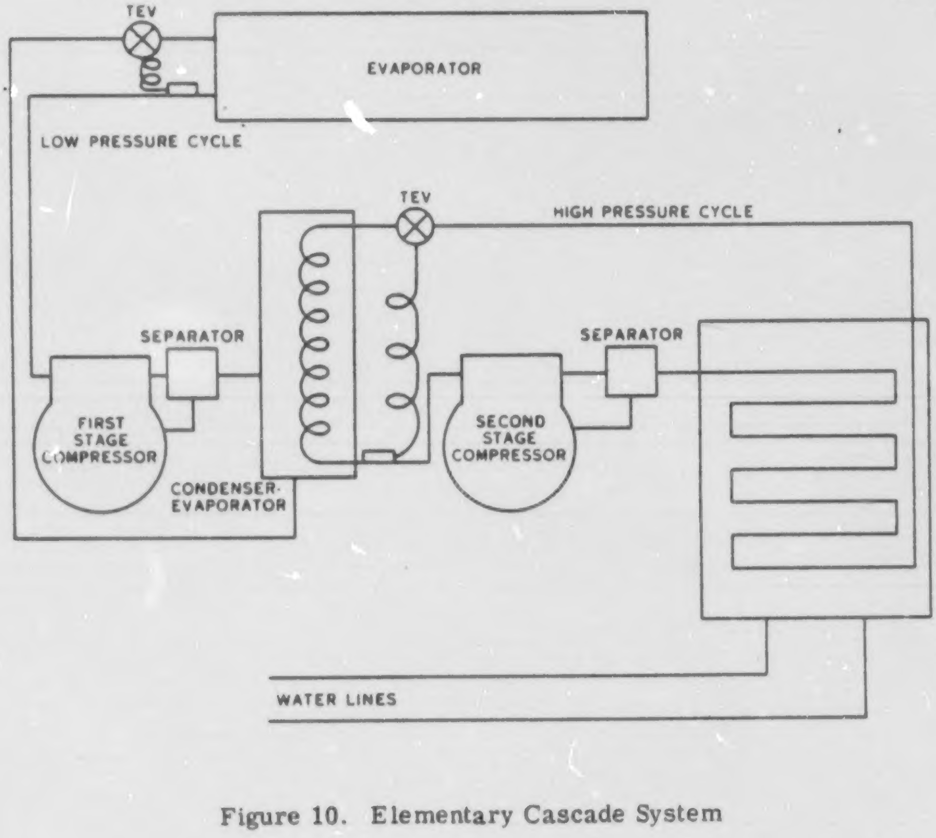
TEV
EVAPORATOR
LOW PRESSURE CYCLE
TEV
HIGH PRESSURE CYCLE
SEPARATOR
SEPARATOR
FIRST STAGE COMPRESSOR
SECOND STAGE COMPRESSOR
CONDENSER-EVAPORATOR
WATER LINES

Figure 10. Elementary Cascade System

Two-Stage Cascade System

The two-stage cascade system is a refinement over the elementary system, in that a heat exchanger has been added. There are several arrangements of the two-stage system as far as the location of the heat exchanger is concerned, but the condenser-evaporator must always be located between the two stages. The cold vapor, figure 11, from the evaporator passes through the heat exchanger where it is heated by the hot liquid from the second stage system. From the heat exchanger it passes to the first stage compressor where it is compressed and discharged into the condenser-evaporator. Here it condenses and turns to a liquid. The liquid passes through the expansion valve into the evaporator completing the first-stage cycle. In the second-stage cycle, the

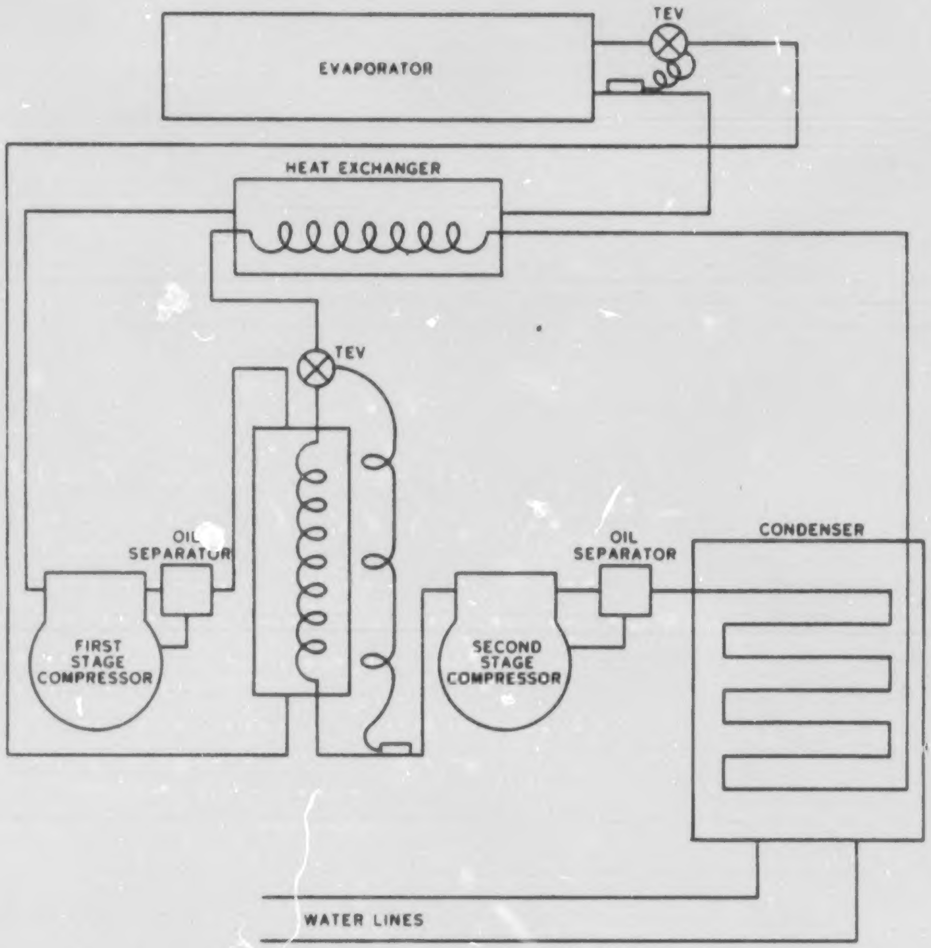
TEV
EVAPORATOR
HEAT EXCHANGER
TEV
OIL SEPARATOR
FIRST STAGE COMPRESSOR
OIL SEPARATOR
SECOND STAGE COMPRESSOR
CONDENSER
WATER LINES

Figure 11. Two-Stage Cascade System

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liquid leaves the condenser and passes to the heat exchanger where it is subcooled by the cold vapor in the first-stage system. It then passes through the expansion valve into the condenser-evaporator where it turns into a vapor, cooling the hot vapor in the first-stage system. From the condenser-evaporator the vapor passes to the second-stage compressor where it is compressed and discharged into the condenser, completing the second-stage cycle.

SUMMARY

Multiple evaporator systems are found most often in restaurants, soda fountains, bars, meat and produce markets. Although multiple installations are used in several different applications, it must not be presumed that any two evaporators may be connected in a multiple system without regard to size, usage, humidity and temperature requirements.

To control the temperature in a multitemperature installation, various combinations of valves and controls must be used, such as solenoid valves and evaporator pressure regulating valves.

Solenoid valves may be placed in either the suction or liquid lines; however, if solenoid valves are used, the size of the receiver must be increased. Check valves must be used to prevent the vapor in the warmest evaporator from backing up into the colder evaporator.

Evaporator pressure regulating valves are designed to maintain a given pressure in the evaporator. They are used in the suction line at the outlet of the evaporator.

There are four different temperature ranges in refrigeration work, high, medium, low, and ultralow.

Each temperature range has its own particular problems, but ultralow temperature ranges present the most complex and critical problems. There are two ways to obtain very low temperatures: direct staging and cascading.

In a direct compounding system, it is necessary to use the same refrigerant but in a cascading system you must use a different refrigerant in each side of the system.

QUESTIONS

1. Name and explain the two classifications of multiple evaporator systems.

2. Name the two methods of controlling the temperature in multiple evaporator systems.

3. When is an accumulator used in a multiple evaporator system?

4. What is the function of the check valve in the system?

5. Name two evaporator pressure regulating valves.

6. Explain the use of the bypass line.

7. Name the four temperature ranges.

8. What are four problems encountered in ultralow temperature?

9. What are the two methods of obtaining ultralow temperature?

10. What is the main purpose of the subcooler in a direct compounding system?

11. What is the indication of wax separation in ultralow temperature systems?

12. What is the purpose of equalizing lines on a multiple compressor system?

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4. Automatic Refrigerant Controls--Alco Valve Company

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COOLING TOWERS

OBJECTIVE

This study guide will help you in learning:

- Purpose and types of cooling towers.
- Major components and construction features.
- Purpose of bleed-off and makeup features.
- Effects of scale, corrosion, algae and turbidity on water towers.
- Installation and maintenance requirements.

Cooling towers (see figure 12) are used to cool the water from the water-cooled condensers of refrigeration and air-conditioning systems. The hot water from the condenser is pumped to the top of the tower, then sprayed on a distribution deck where it passes through holes and falls onto the wetted deck. The cool water falls into the collection pan and the cycle begins again.

Air passing through the tower evaporates some of the water. The heat of evaporation comes from the water itself; therefore, when the water reaches the collecting tank at the bottom of the tower its temperature is 10 to 18° less than it was at the top of the tower. The smaller the droplets of water the more surface area is exposed to the action of the air and the faster the rate of evaporation. The same process takes place here that takes place when a swimmer comes out of the water. As long as the swimmer is under the water and not in contact with the air, he is relatively warm. However, when he steps out of the water into the air, evaporation takes place. The heat for this evaporation comes from the swimmer's body and leaves a feeling of being cold.

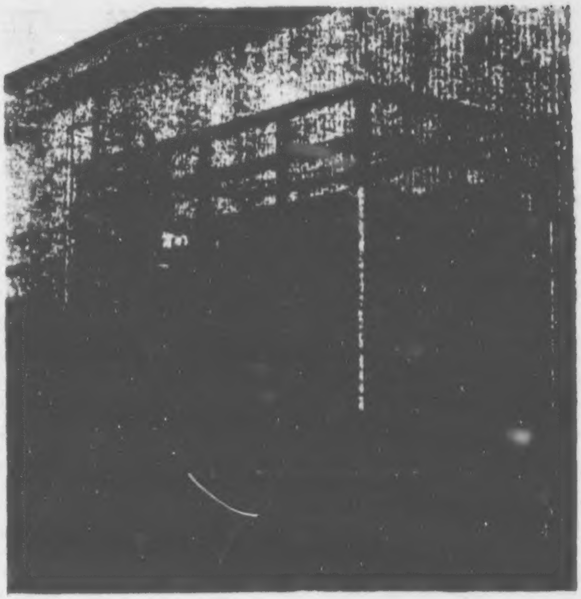

Figure 12. Cooling Towers

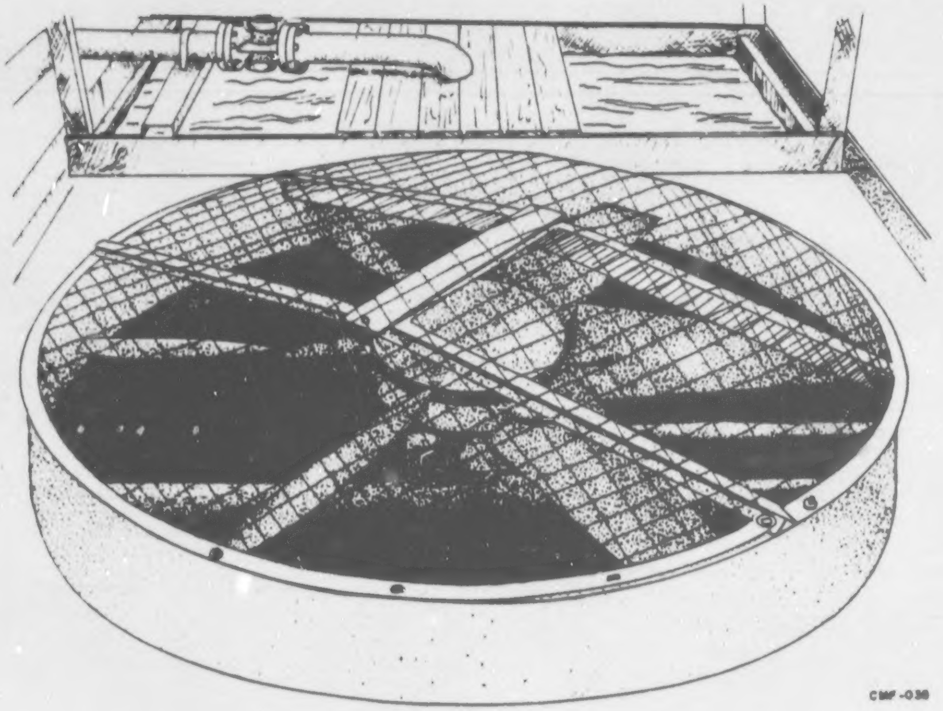

Figure 13. Distributing Deck and Fan

A basic cooling tower (figure 14) consists of water spray, a collecting pan, drain connections, and a structure of louvers or solid panels which form an enclosure or spray chamber. A pump is provided for the recirculation of the cooled condenser water. Most cooling towers are equipped with an adjustable bleed-off to help reduce scale and corrosion.

Types

There are two types of cooling towers; one is the atmospheric or natural draft tower which depends on wind velocity, the other is the forced draft type which uses a fan to force the air through the tower.

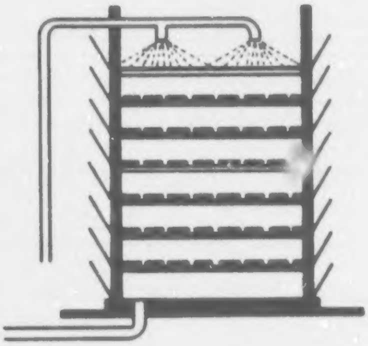

Figure 14. Schematic Diagram of a Natural Draft Cooling Tower

NATURAL DRAFT. A natural draft or atmospheric cooling tower is dependent on natural air movement through its structure for effective operation. This type tower has louvered panels on all four sides to permit the wind to pass through the spray chamber. Structural members of these towers are usually made of steel, and the wetted deck of cypress or redwood. They are normally used for small refrigerating systems and are always located outdoors. To permit maximum circulation of air through them, they are placed a good distance from a building or other wind obstruction. All atmospheric towers must be placed away from wind obstructions to obtain the benefit of prevailing winds during the summer.

Natural draft towers are designed for a 3 to 5 mile wind velocity and are selected to cool the water to approximately 7^{o} above the wet bulb temperature. The amount of water circulated through the tower spray system is at the rate of 5 gallons per minute per ton of refrigeration required.

FORCED DRAFT TOWERS. Forced draft towers are equipped with solid metal panels on all four sides which are mounted on structural steel members with openings for flow of inlet and discharge air. Fans are located either at the inlet or at the outlet of spray chamber depending on manufacturer's particular design. Normally, forced draft towers are used on large refrigerating systems and are installed either indoors or outdoors in any convenient space. Indoor installations are near the outside wall to reduce duct work to and from the outside. Sizes of the ducts are never smaller than the openings of the tower. Restrictions in ducts and louvers, and sharp or square bends are avoided since they reduce the airflow. Forceddraft towers are selected for the same wet bulb temperature. The amount of water circulated through the tower spray system is at the rate of 3 gallons per minute per ton of refrigeration required (see figure 15).

Regardless of whether a natural convection or a forced convection tower is used, an average of 1.8 gallons of water will be evaporated per hour for each ton of refrigeration capacity.

Cooling Tower Components

The spray nozzles are used to distribute and atomize the condenser water to the top of the tower. The distribution deck further distributes the water over the wetted deck. The wetted deck made of redwood or cypress slats slows the water flow aiding in evaporative cooling of the water. Louvers are used to direct the airflow through the tower. The cool water falls into the collection pan or sump. An overflow pipe is installed in the sump to reduce water spillage and can be used for bleed-off control. The bleed-off line may also be installed on the water line from the condenser to the spray nozzles. The float valve is installed in the water makeup line to start and stop the flow of makeup water. The water circulating pump supplies cool water from the cooling tower sump through the water-cooled condenser, to the spray nozzles (figure 15).

The forced draft tower has a fan to force air through the tower and eliminators to prevent water being pulled out by the fan.

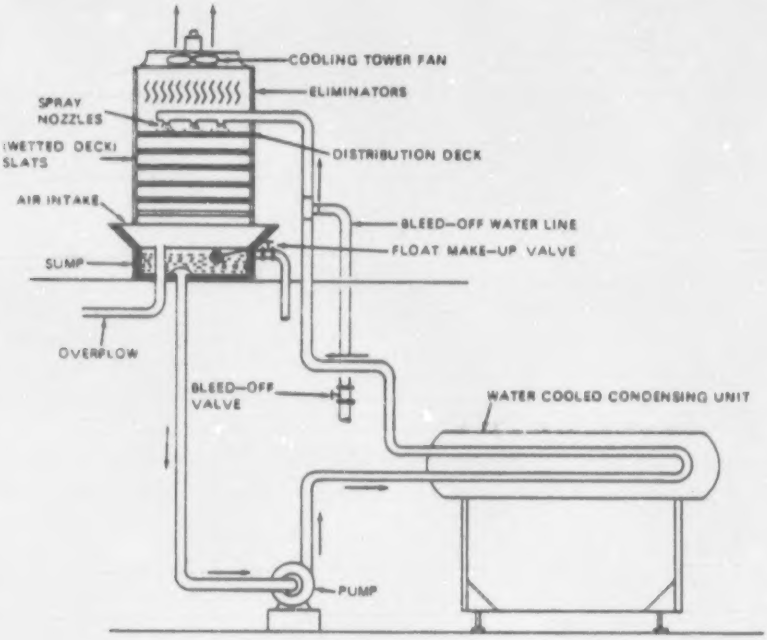
COOLING TOWER FAN
ELIMINATORS
SPRAY NOZZLES
(WETTED DECK) SLATS
DISTRIBUTION DECK
AIR INTAKE
BLEED—OFF WATER LINE
FLOAT MAKE—UP VALVE
SUMP
OVERFLOW
BLEED—OFF VALVE
WATER COOLED CONDENSING UNIT
PUMP

Figure 15. Schematic Diagram of a Mechanical Draft Cooling Tower

Cooling Tower Piping

Condenser water-circulating piping is usually of galvanized steel pipe and cast-iron fittings. Sufficient numbers of valves, flanges, and unions are installed so that the pump and condenser may be disconnected easily. Gate valves are used in the lines since they offer less resistance to the water flow. Globe type drain and vent valves are installed at all low and high points to drain or vent the piping system. Multicondenser systems have valves on inlet and outlet water connections to each condenser so that condensers may be disconnected without interfering with the operation of the rest of the condenser water circulating system. Pipe connections to the cooling tower, condenser, and pumps should never be smaller than the inlet or outlet connections of the equipment. The pump inlet connection to the cooling tower pan is always the same pipe size as the fitting on the pan for a distance of 5 feet if the connection is vertical, and for the entire length if it is horizontal. The pump inlet connection at the tower pan is protected by a wire screen to prevent debris from entering the piping system.

Cooling towers have provisions for adequate bleed-off to keep down concentration of solids in water. This is done by installing a bleeder line from the spray nozzle header to the drain, similar to the bleeder line on evaporative condensers. Makeup water replaces the water that has been lost due to evaporation, wind drift, overflow, and bleed-off.

Capacity Control

The amount of heat removed from the condenser may be controlled by one of the following methods. When these methods are used together, there is a more efficient control. Figure 16 shows the three main capacity control systems.

MODULATING VALVE. This valve is operated by a Series 90 electric motor and a thermostat. The thermostat senses the temperature of the water leaving the condenser. It has an insertion type sensing element that is installed in the outlet waterline from the condenser. The thermostat is set for a desired temperature. When the condenser water temperature rises to the cut-in setting on the thermostat the bypass portion of the valve closes. This allows the water to flow from the condenser to the tower.

CYCLING FAN. In this method of capacity control the cooling tower fan is cycled by a pressurestat that is connected to the compressor discharge line. When the discharge pressure increases, the pressurestat will cycle the fan to the on position. This removes the heat from the water, reducing the pressure. When the discharge pressure decreases to the pressurestat setting, the fan is cycled off.

MODULATING DAMPERS. These dampers are located in the tower fan discharge airflow. The operation of the dampers is controlled by a pneumatic thermostat. A pneumatic damper operator positions the dampers according to what is called for by the thermostat. A remote bulb sensing element is installed in the collecting pan of the cooling tower. When the condensing pressure increases, the tower water temperature increases. This is sensed by the thermostat. The thermostat sends a signal to the controller to open the dampers. This allows more air to go through the tower to remove the heat. When the temperature is reduced, the thermostat signals the damper operator to close the dampers.

Cooling Tower Maintenance

Cooling towers can be kept clean and operating efficiently with one service call per month. The following preventive maintenance procedures will guarantee a clean trouble-free system. It will be noted that there is nothing complicated about any of the steps. All of the following steps are necessary but the most important factor to remember is that they must be performed regularly.

SERVICE PROCEDURES. Following are procedures for servicing cooling towers:

1. Keep the water free of dirt and circulating at full rate. As often as required, clean out any clogged spray nozzles and clean slime and foreign matter from water distribution pan. At least once a month drain and flush the dirt out of the cooling tower Clean all screens and make sure all lines and pipes are unrestricted.

2. Make sure bleed-out is working. Install a bleed line that will not plug up. Install this line so that the amount of bleed can be measured and changed as required. For most systems the bleed rate should be two gallons per hour per ton. If the equipment is large or if the makeup water is exceptionally hard it may require the use of a water chemist to determine the correct amount of bleed.

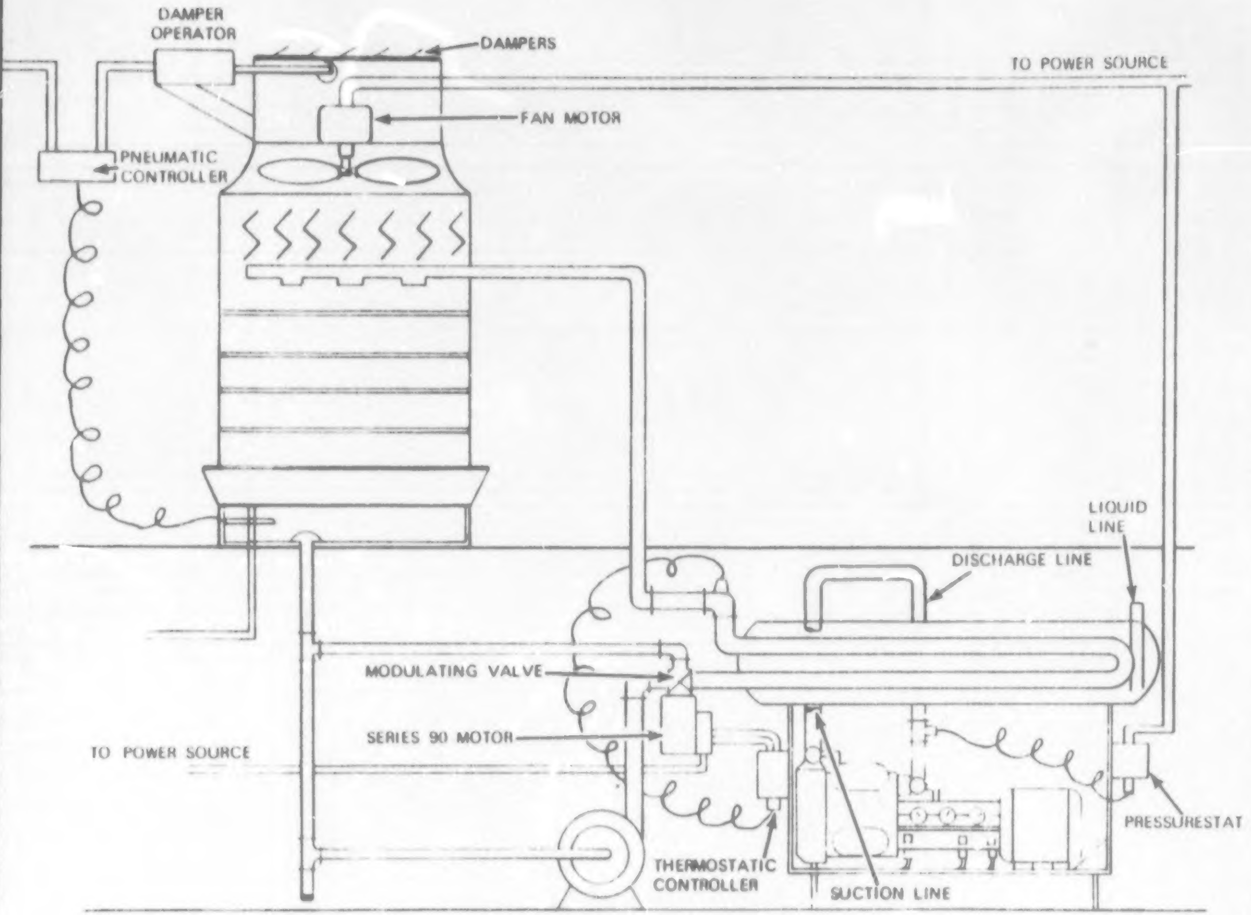
DAMPER OPERATOR
DAMPERS
TO POWER SOURCE
FAN MOTOR
PNEUMATIC CONTROLLER
LIQUID LINE
DISCHARGE LINE
MODULATING VALVE
SERIES 90 MOTOR
TO POWER SOURCE
PRESSURESTAT
THERMOSTATIC CONTROLLER
SUCTION LINE

Figure 16. Cooling Tower Capacity Control Diagram

The requirements for satisfactory bleed are as follows:

- Flows at the desired rate at all times.
- Does not plug up or reduce rate between service calls.
- Cannot be easily tampered with by unauthorized persons.
- Flow rate can be easily measured and reset as required.

3. Maintain adequate concentration of phosphates in the system. Phosphates are primarily used to control the formation of scale. It will also control corrosion, but larger amounts of the chemical must be used.

4. Keep algae growth controlled by adding appropriate algaecides.

5. Make physical inspection for corrosion so that corrective steps can be taken if evidence of corrosion is found.

6. Determine cleanliness of heat transfer surfaces. Note any abnormal increase in head pressure or temperature which may indicate fouled up heat exchanger surfaces or water piping.

LOCATION OF BLEED LINE. The bleed line should be located as illustrated in figure 17.

One or both points A and B must be higher than the water level in the pan to prevent the water from syphoning out when the system is not running.

Leave enough clearance between pipe cap and drain, so quart bottle can be used to measure bleed rate.

Bleed rate can be measured by determining the number of seconds it takes to fill a quart bottle. Bleed rate in gallons per hour equals 900 divided by the number of seconds required to fill the bottle.

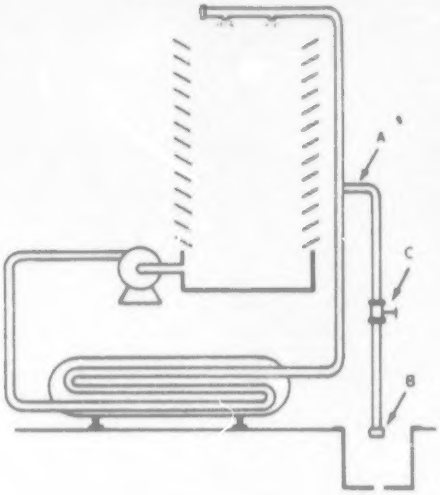

Figure 17. Location of Bleed Line

Safety Precautions

When work is being performed on the tower all electrical switches should be in the off position. This should prevent the accidental operation of units during maintenance. Protective clothing should be worn when transferring chemicals from their containers to the feeders.

SUMMARY

Cooling towers are an important part of air-conditioning systems, and if taken care of will give many years of trouble-free service.

The types of cooling towers are natural draft and forced draft systems.

Cooling tower piping, types of fittings, and types of valves must meet the requirements for the application of the system.

A capacity control system must be used that will allow the system to handle the maximum refrigeration load and also operate at reduced loads. Capacity control is usually provided for by using a modulating water valve that is operated by head pressure.

Cooling tower maintenance and service procedures should be followed to insure an operational system with as little downtime as possible. This can be accomplished by correct water treatment and keeping the system clean.

QUESTIONS

1. What are the two types of cooling towers?

2. At what wind velocity are natural draft towers designed to operate?

3. What is the evaporation rate?

4. What is the purpose of the bleed-off?

5. What do we use to control algae growth?

6. What is the formula used to figure bleed-off rate?

7. Why must there be a clearance between pipe and drain?

8. When using a forced draft tower, how much water must be circulated through the tower?

REFERENCES

1. AFM 85-18, Maintenance and Operation of Refrigeration, Air-Conditioning, Evaporative Cooling and Mechanical Ventilating Systems

2. Trane Air-Conditioning Manual

WATER PUMPS

The installation and maintenance of centrifugal pumps are your responsibilities. To properly maintain an enclosed chilled water system, one must be able to service the centrifugal pump. The pump moves the chilled water through the system. You will also be called upon to service the centrifugal pumps used to circulate water in a cooling tower condensing system.

Centrifugal pumps may be either single or double suction. In the single-suction pump the water enters from one side of the impeller only. In the double-suction type the water enters the impeller from both sides. Centrifugal pumps may also be classified as single or multiple stage. By staging, we mean the number of impellers the water must go through before it goes to the outlet of the pump. In a three-stage pump, the first impeller would pick up the water, put it in motion and discharge it to the inlet of the second impeller. The second impeller adds more motion to the water and passes it along to the third impeller. The third impeller adds more motion to the water and discharges it to the outlet of the pump. By using three or more stages it is possible to lift water 100 feet or more.

Most centrifugal pumps used in refrigeration work are of the single-suction single-stage type.

Principle of Operation

The centrifugal pump utilizes the throwing force of a rapidly revolving impeller. The liquid is pulled in at the center of the impeller and is discharged at the outer rim of the impeller. By the time the liquid reaches the outer rim of the impeller, it has acquired a considerable velocity. The liquid is then slowed down by being led through a volute (a gradually widening channel in the pump casing). See figure 18. As the velocity decreases, the pressure increases. It is this pressure which enables the pump to move the liquid.

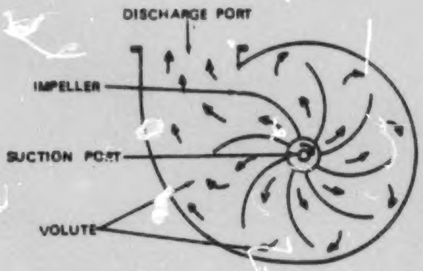

Figure 18. Simple Centrifugal Pump

Centrifugal Pump Characteristics

A centrifugal pump is not a positive displacement pump. That is, it will not deliver the same amount of water all the time. In fact, one of the main characteristics of a centrifugal pump is the relationship of the amount of water it will deliver against a given pressure. A centrifugal pump may deliver 100 gallons per hour at 20 psi pressure but as the pressure is increased the pump will not deliver as much water.

Each centrifugal pump has a pump characteristic curve (see figure 19) that shows the quantity of water that the pump will produce at different pressures. You will notice that as the pressure increases at 100 psi, the gallons per minute reduces to zero.

The pressure against which a pump can operate and the amount of water it will deliver at that pressure depends directly on the speed of the impeller.

Three factors must be considered when selecting a pump to do a given job.

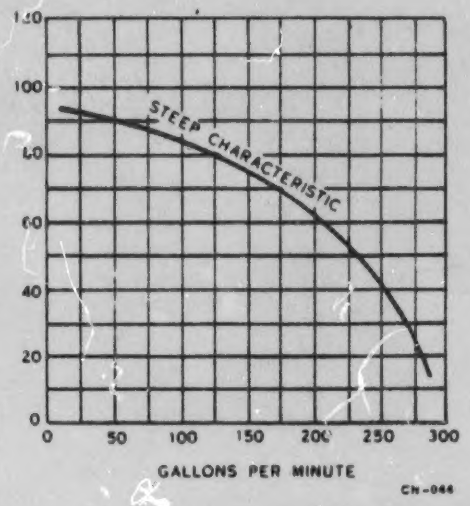

Figure 19. Pump Characteristic Curve

1. The quantity of water delivered varies directly with the pump speed.
2. The pressure developed varies as the square of the speed.
3. The horsepower required varies as the cube of the speed.

For practical interpretation, the first factor says that if the speed of the pump is doubled, the amount of water delivered will also be doubled.

EXAMPLE: Assume the speed of the pump is 1,000 rpm and the water is flowing at a rate of 75 gallons per minute. Now increase the speed to 2,000 rpm; the rate of waterflow will increase to 150 gallons per minute.

The second factor says that if the speed is doubled the pressure will increase four times.

EXAMPLE: Assume the speed is 1,000 rpm and the pressure developed is 20 psi. By increasing the speed to 2,000 rpm we increase the pressure to 80 psi.

The third factor states that if the speed is doubled the horsepower required to drive the pump must be increased eight times.

EXAMPLE: Assume we can use a one-horsepower motor to drive a pump at a speed of 1,000 rpm and produce a pressure of 20 psi and a waterflow rate of 75 gallons per minute. Now increase the speed of 2,000 rpm. The water flow rate will increase to 150 gallons per minute and the pressure will increase to 80 psi but we must use an eight-horsepower motor to drive the pump.

An additional characteristic is that centrifugal pumps are not self priming, because they will not pump air. Therefore, the pump and pipe must be full of water before the pump is started. Filling the pump prior to starting is called priming. Before priming, you should make sure all the connections between the pump and the water in the well are airtight. Remove the priming plug from the pump and fill the pump and pipe with water. This must be done slowly so the air in the pipe has a chance to escape. It is very obvious that there must be something installed in the end of the pipe to keep the water from running out as fast as you put it in. This unit is a foot valve. It is so designed to allow water to pass through it from the well to the pump but will close if the water tries to run from the pump back into the well.

Centrifugal Pump Components

Every pump has a power end. This is usually an electric motor. The motor shaft is connected to the impeller shaft by means of a flexible coupling. The other end of the pump is the fluid end. This consists of the suction port, discharge port, the volute (or impeller housing), and the impeller. The impeller shaft must be properly supported. Bearings are used to center the shaft and allow for smooth rotation. To keep the pump from leaking at the point where the shaft goes through the housing, packing is installed. This packing is held in place by a packing gland.

Head Pressure

We have been speaking about the pressure that the pump develops. This is known as the head pressure. It is the sum total of the following pressures: Pumping head; Static head; Friction head.

PUMPING HEAD. Assume you had a pump that would deliver 150 gallons per minute only 100 gallons per minute is allowed to flow. The pump will develop a given pressure. This is known as the pumping head because the pump must operate against this pressure before it can deliver any water.

STATIC HEAD. The purpose of any pump is to raise water from one level to another. A pump may do this by either lifting the water, pushing the water or a combination of both ways (see figure 20). A pump cannot efficiently lift water more than 22 feet. It can push water approximately 2 feet per psi developed. The distance from the pump down to the water is known as the suction lift distance. The distance the pump pushes the water above the pump is known as the boost distance. The static head is the sum of both the lift and boost distance. Let us assume we have a pump located at the top of a ten-foot well. We are going to pump the water into a tank 50 feet above the ground. The static head would be equal to the weight of water in a vertical pipe 60-feet high. The pump must overcome the static head pressure in order to move the water from the well to the tank.

FRICTION HEAD. Any time you force liquid through a pipe the walls of the pipe have a tendency to restrict the flow of the liquid. The pressure required to overcome this restriction is known as the friction head. The friction head is equal in a given pipe regardless of whether it is installed vertically or horizontally. It is obvious, the longer the pipe and the faster the flow rate the higher the friction head. The friction head can be reduced by using pipes with a large inside diameter and a clean smooth inside surface.

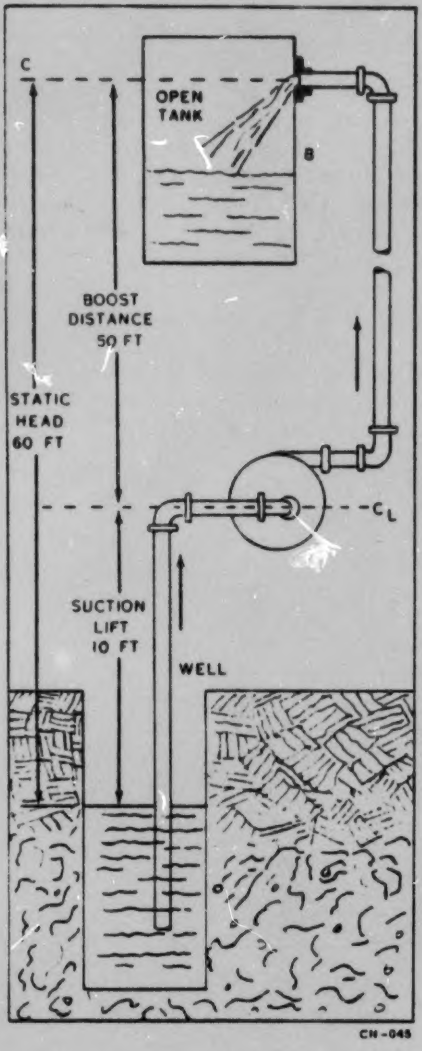
C
OPEN TANK
B
BOOST DISTANCE 50 FT
STATIC HEAD 60 FT
SUCTION LIFT 10 FT
WELL
C_L
CN-045

Figure 20. Static Head

No-Delivery Head

If the discharge line is shut off so that no water is being delivered, the pump will continue to run and maintain a given pressure in the system. This pressure is known as the no-delivery head. The no-delivery head pressure is normally a little higher than the pumping head pressure. Centrifugal pumps will not develop enough pressure to be dangerous. However, the pump should not be allowed to run for long periods of time with the discharge line closed. A pump that is running without delivering any water has no load.

Installation

A concrete foundation must be laid before a centrifugal pump can be installed. Figure 21 shows the concrete foundation that is necessary to provide a strong enough base to withstand pump vibration and maintain alignment of the pump and motor. A one-inch clearance should be left between the foundation and the pump base. This is done to allow for grouting. The correct size bolts should be placed in the concrete before the concrete hardens. A drawing or template should be used in locating the bolts. A piece of pipe with a diameter 2 1/2 times larger than the bolt is placed in the position of the bolt. This is done to allow movement of the bolts and to align the pump and the motor. A washer is placed between the head of the bolt and the pipe to hold the bolt in place. The bolts should be long enough to stick up through the nut after the pump has been installed. Wedges are placed near the center of the motor and pump, sometimes near the middle of the bedplate. The wedges provide for the leveling of the bedplate and the proper clearance for grouting.

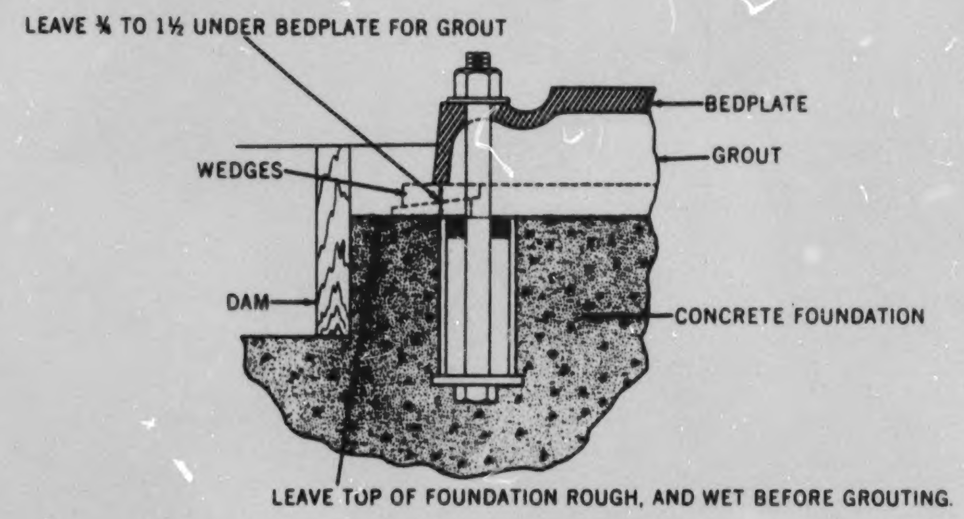
LEAVE ¾ TO 1½ UNDER BEDPLATE FOR GROUT
BEDPLATE
GROUT
WEDGES
DAM
CONCRETE FOUNDATION
LEAVE TOP OF FOUNDATION ROUGH, AND WET BEFORE GROUTING.

Figure 21. Pump Foundation

Tighten the foundation bolts evenly and fingertight after the wedges have been adjusted. Be sure the bedplate is still level. Final tightening of the foundation bolts is made after the grout has set for 48 hours.

Removal

The pump and motor assembly may be removed after removing the nuts from the foundation bolts. Lift the assembly from the bedplate. If only the motor or pump is to be removed, unfasten the holddown bolts on either one. Disconnect the coupling and lift the unit out.

INSTALLATION OF THE FLEXIBLE COUPLING

Steelflex Coupling

The coupling comes in two pieces. They are referred to as halves. Remove the motor holddown bolts and slide the motor back to increase the distance between the motor and the pump shafts. Slide one of the halves on the pump shaft and the other on the motor shaft. The slot key is used to position the two halves. Tighten the setscrews to hold the halves in place. The halves are pushed together by remounting the motor. Press the steelflex spring into place around the coupling halves as shown in figure 22. The coupling cover comes in two pieces. Install the halves in the rubber retainers and bolt them together.

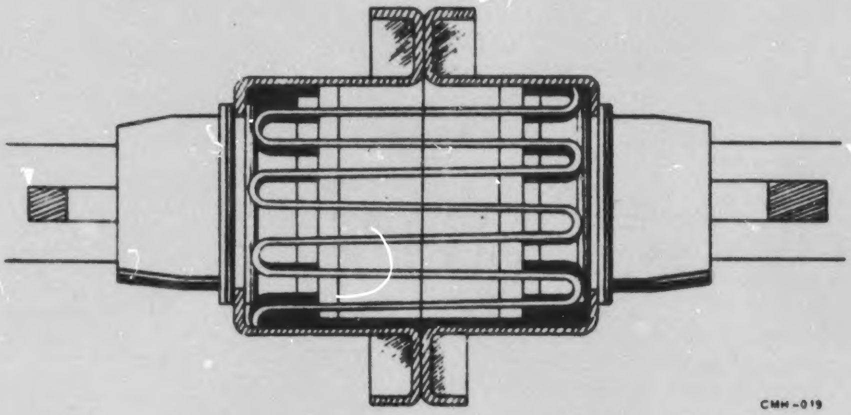

Figure 22. Steelflex Coupling

Spider Insert Type Coupling

Before installing this coupling the motor holddown bolts should be removed and the motor pushed back to make enough clearance to install the coupling halves, one on each shaft. The halves may be secured on the shafts by setscrews. A rubber grommet is placed between the halves as the motor is being installed and the halves are being pulled together.

The motor and pump halves can be brought into alignment by adjusting the wedges and tightening the pump and motor holddown bolts. Check the gap and angular alignment on the coupling. The coupling shown in figure 23 is the "Spider Insert" type. The normal gap is one-sixteenth of an inch. The gap is the difference in the space between the coupling halves and the thickness of the spider insert. Angular alignment, a bend in the coupling, may be checked by using calipers at four points on the outer ends of the coupling hubs, at 90° intervals as shown in figure 23.

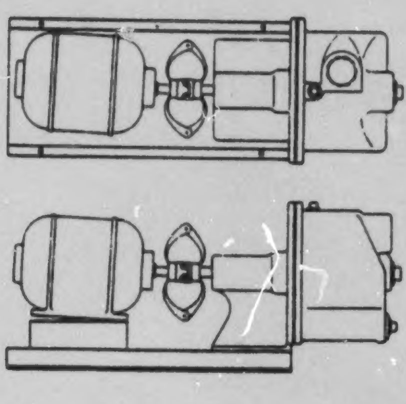

Figure 23. Checking Angular Alignment

When the measurements show the ends of the coupling hubs to be the same distance apart at all four points, the unit will be in angular alignment. The motor holddown bolts are loosened and the motor shifted or shimmed to obtain gap and angular alignment. The bolts are tightened down after the adjustments have been made.

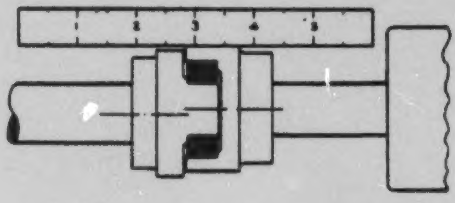

Figure 24. Checking Parallel Alignment

Alignment of the pump and motor through the flexible coupling is very important for trouble-free mechanical operation. The following steps must be followed to start alignment of the pumping unit:

1. Tighten the foundation bolts.

2. Tighten the pump and motor holddown bolts.

3. Check the gap and angular adjustment.

4. Check parallel alignment by laying a straightedge across both coupling rims at the top, bottom, and both sides, as shown in figure 24. When the straightedge rests evenly on both halves of the coupling at each side, the unit will be in horizontal parallel alignment. The vertical difference of the shafts should be measured with a straightedge and feeler gage. To establish parallel alignment, thin shim stock is placed under the motor base. Occasionally, shims may be required under the pump base.

5. Caution: Alignment in one direction may alter the alignment in another. Check through each alignment procedure after making an alignment change.

Coupling Removal

The spider type coupling may be removed by using the following steps:

1. Loosen the holddown bolts on the motor and slide the unit back enough to expose the grommet.
2. Remove the grommet. This exposes the end of the shaft.
3. Use a wheel puller to remove the coupling halves. This forces the halves straight off the shaft. A mallet may be used to tap the halves off.

Steelflex Coupling

Remove the coupling cover and the steelflex spring. Slide the motor back after removing the holddown bolts. The setscrews in the coupling should be loosened. Use a wheel puller to remove the halves to prevent damage to the shaft or bearings.

SUMMARY

Centrifugal pumps consist of a rapidly rotating impeller in a casing. The purpose of the impeller is to increase the velocity of the water. The amount of water that a pump can deliver depends on the horsepower, impeller speed, and the total head pressure.

Flexible couplings are used to connect pumps to motors and to eliminate vibrations.

QUESTIONS

1. Define the following terms in relation to centrifugal pumps?
    a. Pumping head
    b. Static head
    c. Friction head
2. What is meant by single-stage pumps?

3. What is meant by multistage pumps?

4. What is the purpose of any pump?

5. What are the characteristics of a centrifugal pump?

6. What are two types of couplings?

7. What instrument is used for parallel and angular alignment?

8. Why does the packing permit a small amount of water leakage?

REFERENCES

1. AFM 85-18, Maintenance and Operation of Refrigeration, Air-Conditioning, Evaporative Cooling and Mechanical Ventilating Systems
2. Trane Air-Conditioning Manual
3. Principles of Refrigeration (Centrifugal Pumps), Dossat and Wiley

WORKBOOKS 3ABR54530-VI-1-P1 thru VI-3-P2

Department of Civil Engineering Training

Refrigeration and Air-Conditioning Specialist

MULTIPLE REFRIGERATION SYSTEMS, EVAPORATIVE COOLING TOWERS AND WATER PUMPS

January 1975

SHEPPARD AIR FORCE BASE

11-8

Designed For ATC Course Use

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REFRIGERATION AND AIR-CONDITIONING SPECIALIST

(Days 46-50)

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This supersedes SG 3ABR54530-VI-1 thru 3 and WBs 3ABR54530-VI-1-P1 thru VI-3-P1, 31 October 1973.
Copies of the superseded publication may be used until the supply is exhausted.

Department of Civil Engineering Tng
Sheppard AFB, Texas

WB 3ABR54530-VI-1-P1
22 January 1975

SINGLE-TEMPERATURE MULTIPLE EVAPORATOR SYSTEM

OBJECTIVE

1. To identify single temperature multiple evaporator components,
2. To identify system's electrical components,
3. To trace refrigerant and current flow through the system,
4. To service, adjust and operate a single-temperature multiple evaporator system.

PART I

1. Use the schematic, figure 1, and identify the major components.
2. Write what each component does in relation to the system's operation.

A. ______________________________
____

B. ______________________________
____

C. ______________________________
____

D. ______________________________
____

E. ______________________________
____

F. ______________________________
____

3. Show direction of refrigerant flow by using arrows.
4. Draw a line separating the high side from the low side.

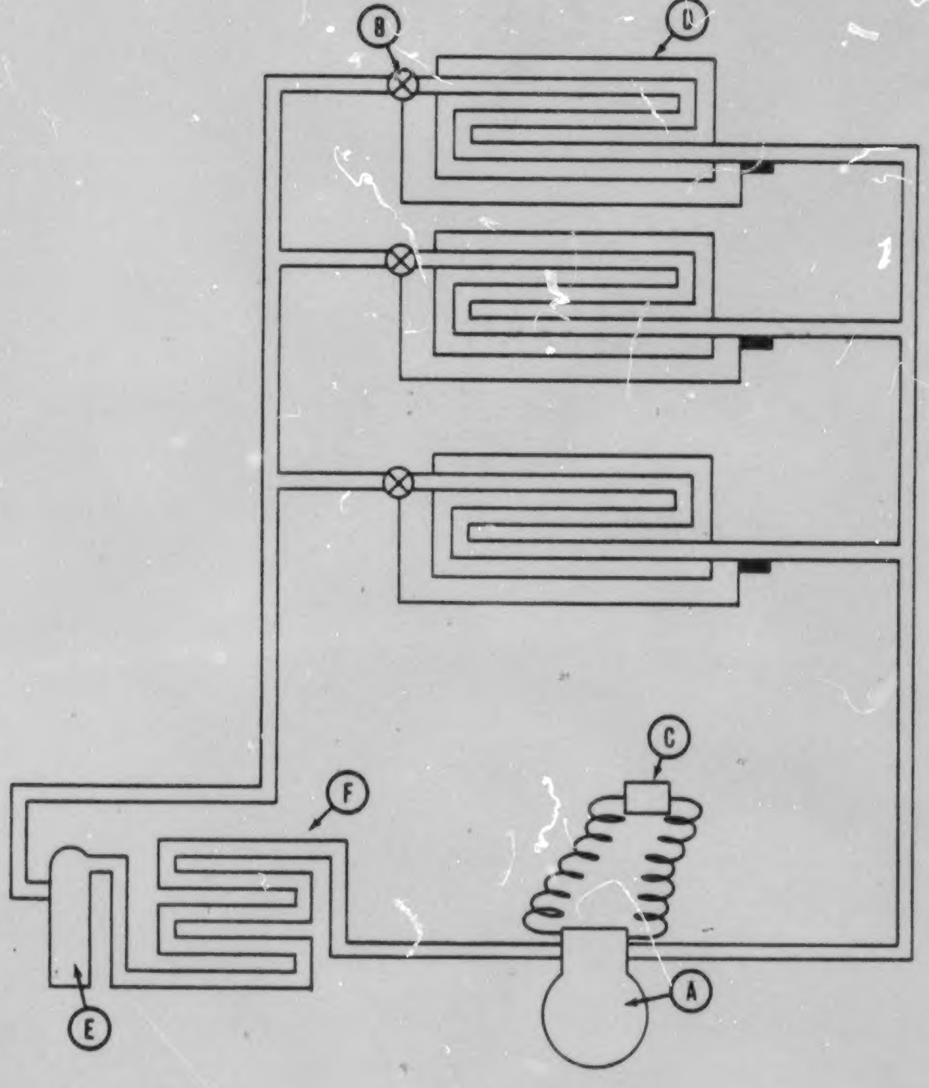

Figure 1. Single-Temperature Evaporator System

PART II

Use the schematic in figure 2 for component identification.

Write their names in the following blanks and state their purpose beside the name.

A. ______________________________

____

B. ______________________________

____

C. ______________________________

____

D. ______________________________

____

E. ______________________________

____

F. ______________________________

____

G. ______________________________

____

H. ______________________________

____

I. ______________________________

____

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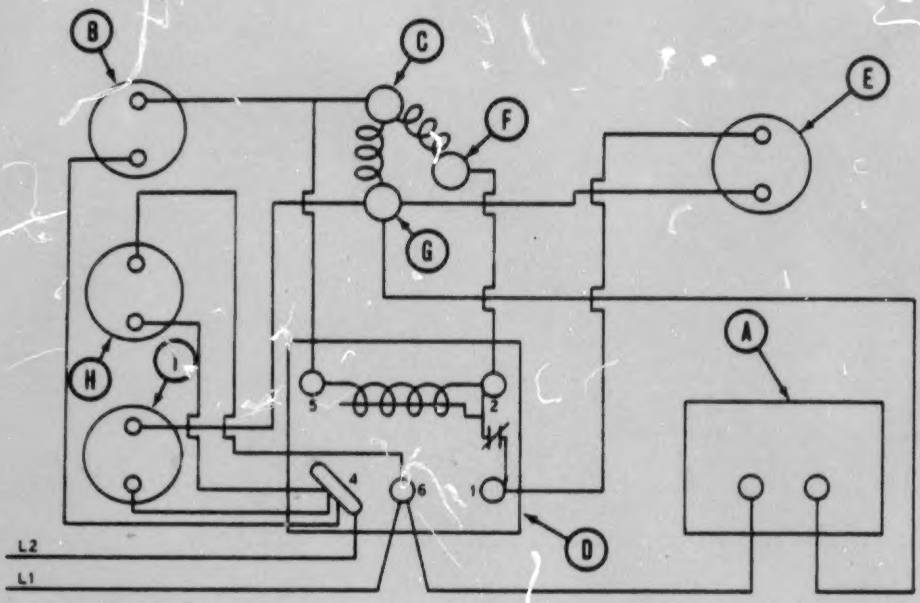
B
C
F
E
G
H
I
A
D
5
2
4
6
1
L2
L1

Figure 2. Single-Temperature Evaporator Electrical System

3. Study the electrical schematic in figure 2.

4. Draw lines on figure 3 connecting the components for correct flow through the system.

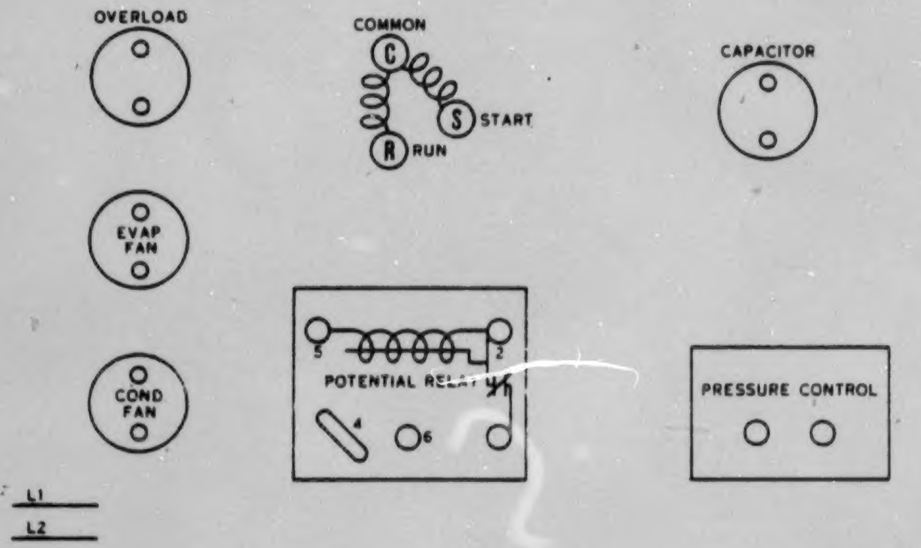
OVERLOAD
COMMON
C
S
START
R
RUN
CAPACITOR
EVAP
FAN
COND
FAN
5
2
POTENTIAL RELAY
4
6
PRESSURE CONTROL
L1
L2

Figure 3. Single-Temperature Evaporator Electrical System

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PART II

PROCEDURE

Accomplish all preoperational checks listed below prior to operation of the trainer and observe the listed procedures closely during all operations.

1. Locate trainer assigned by instructor.

2. Perform preoperational checks for:

   a. Frayed or loose wiring.

   b. Refrigerant line connections for security of fittings.

   c. Master switch for off position.

   d. Condenser fan switch for off position.

   e. Removal of all obstructions.

3. Operational safety checks.

   a. Wear goggles while installing gages and adding refrigerant.

   b. Install manifold gages.

   c. Place suction and discharge service valves in gage position and open king valve.

   d. Observe manifold gage assembly for proper operating pressures.

4. Open the manual bypass valves and turn thermostats to their coldest setting.

   NOTE: This will bypass the evaporator pressure regulator valves and the solenoid valves will remain open.

5. Adjust the pressure control to cut in and cut out at a selected box temperature range.

   a. Cut-in ______________ psi.

   b. Cut-out ______________ psi.

6. Operate the system.

7. Check the box temperature with a thermometer.

8. Make adjustments, if necessary, to maintain temperature range.

9. When the pressure in the common suction line reaches the cut-out point on the pressure contol, the unit will ______________________________

10. It starts again when the suction pressure reaches ____________ psi.

11. Have instructor check your work.

12. Postoperational checks.

    a. Pump the system down using previously taught procedures.

    b. Use goggles while backseating service valves and remove manifold gage lines.

    c. Check all switches for OFF positions.

13. Have instructor check your work.

Checked by ______________________
(Instructor)

2B- 75-1058

SOLENOID VALVE MULTIPLE EVAPORATOR SYSTEM

OBJECTIVE

1. To identify solenoid valve multiple evaporator components,
2. To identify system's electrical components,
3. To trace refrigerant and current flow through the system,
4. To service, adjust and operate a solenoid valve multiple evaporator system.

PART I

1. Use the schematic of a solenoid valve multitemperature evaporator system in figure 4.
2. Identify all refrigeration system components and write their names in the blanks below.

A. ______________________________

____

B. ______________________________

____

C. ______________________________

____

D. ______________________________

____

E. ______________________________

____

F. ______________________________

____

G. ______________________________

____

H. ______________________________

____

I. ______________________________

____

3. Show the direction of flow by arrows.

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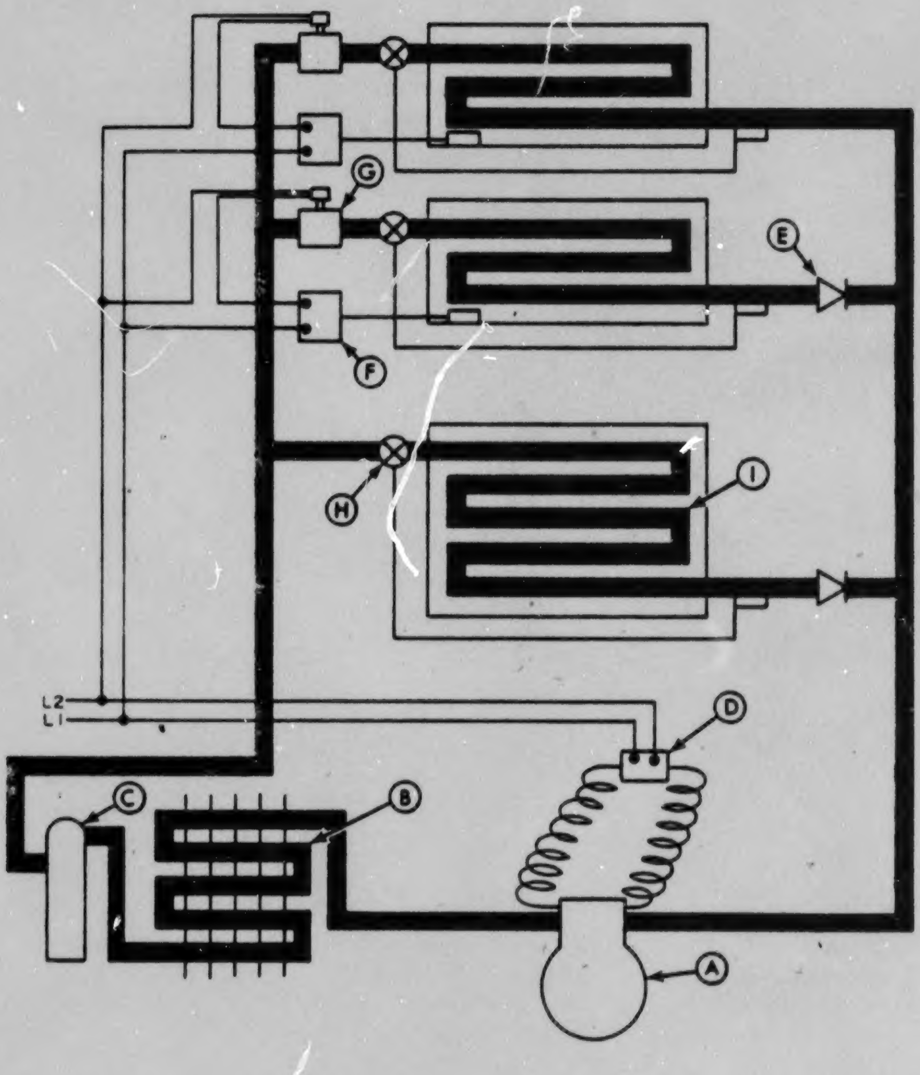

G
E
F
H
I
L2
L1
D
C
B
A

Figure 4. Solenoid Valve Multitemperature System (Liquid Line)

107

PART II

1. Study the wiring diagram in figure 4 of SG 3ABR54530-VI-1.
2. Start at L1 or L2 in figure 5 and draw lines connecting the components for correct operation and current flow.

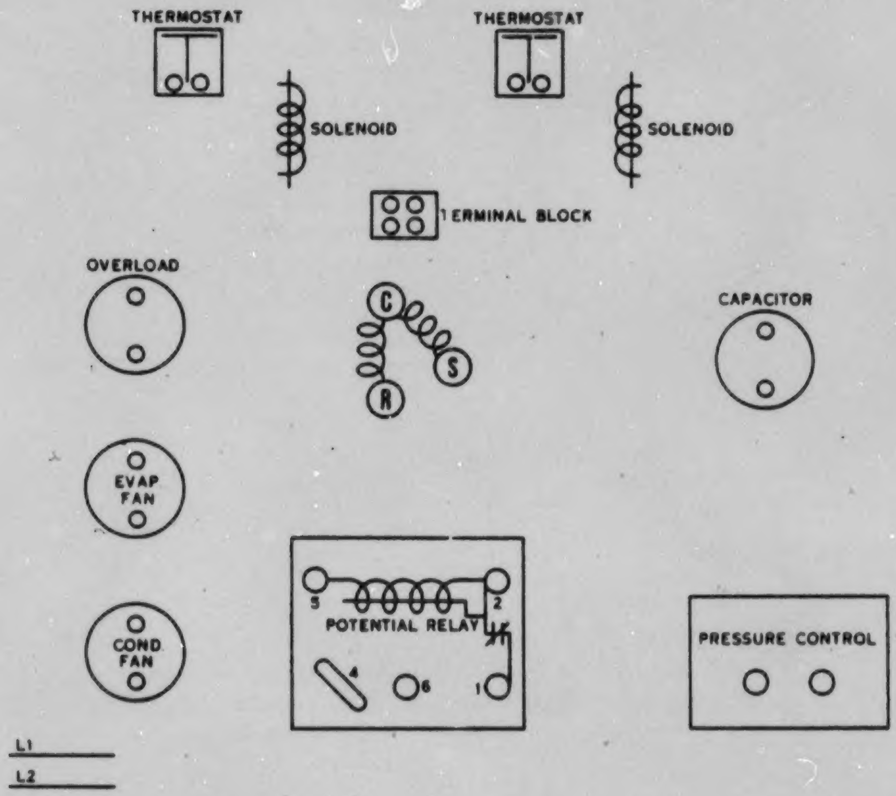
THERMOSTAT
THERMOSTAT
SOLENOID
SOLENOID
TERMINAL BLOCK
OVERLOAD
C
S
R
CAPACITOR
EVAP FAN
5
2
POTENTIAL RELAY
4
6
1
PRESSURE CONTROL
COND FAN
L1
L2

Figure 5. Solenoid Valve Multitemperature Electrical System

117

PART III

PROCEDURE

Accomplish all preoperational checks listed below prior to operation of the trainer and observe the listed procedures closely during all operations.

1. Locate trainer assigned by the instructor.
2. Perform preoperational check for:
   a. Frayed or loose wiring.
   b. Refrigerant line connections for security of fittings.
   c. Master switch for off position.
   d. Clearance of all obstructions.
3. Operational safety checks.
   a. Wear goggles while connecting gages, and adding refrigerant.
   b. Install manifold gages.
   c. Place suction and discharge service valves in gage position and open king valve.
   d. Observe manifold gage assembly for proper operating pressure.
4. Open the manual bypass valve.

   NOTE: This will bypass the evaporator pressure regulator valves.
5. Service the system for operation.
6. Adjust the thermostats and pressure control for desired box temperatures.
   a. Box #1 ____________ °F
   b. Box #2 ____________ °F
   c. Box #3 ____________ °F
7. Operate the trainer.
8. Have the instructor check your trainer when it cycles on the correct temperatures.

9. Postoperational checklist.

   a. Disconnect source of electrical power.

   b. Pump system down using previously taught procedures.

   c. Use goggles while backseating service valves and remove manifold gage lines.

   d. Check all switches for OFF position.

10. Have instructor check your work.

Checked by ______________________________
(Instructor)

EVAPORATOR PRESSURE REGULATOR MULTIPLE EVAPORATOR SYSTEM

OBJECTIVE

1. To identify system's components,
2. To trace refrigerant flow through the system,
3. To service, adjust and operate an evaporator pressure regulator multiple evaporator system.

PART I

1. Use the schematic of the EPR valve system in figure 6.
2. Write the names of the components from the schematic in the blanks below. State their purpose.

A. ______________________ ______________________

______________________ ______________________

B. ______________________ ______________________

____

C. ____

____

D. ____

______________________ ______________________

E. ____

____

F. ____

____

G. ____

____

H. ____

____

I. ____

____

3. Draw arrows showing direction of refrigerant flow.

111

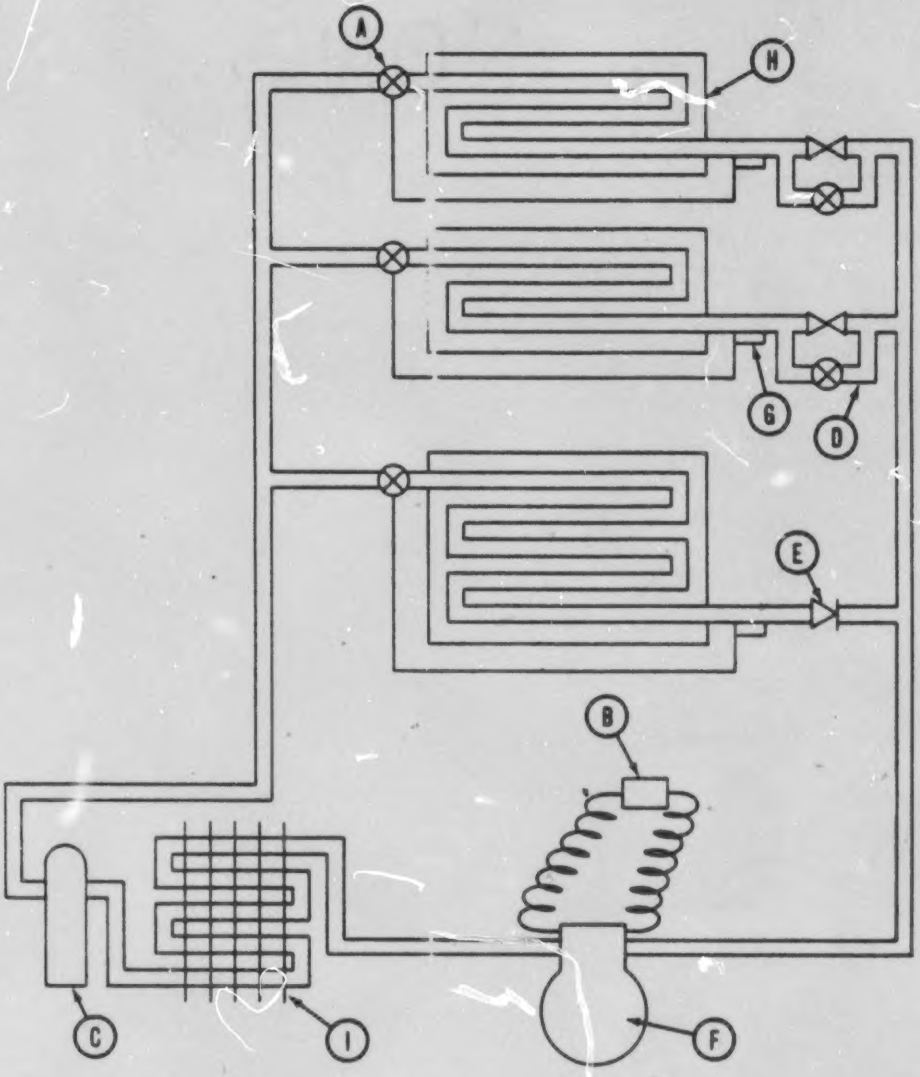

Figure 6. Evaporator Pressure Regulator System

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PART II

PROCEDURE

Accomplish all preoperational checks listed below prior to operation of the trainer and observe the listed procedures closely during all operations.

1. Locate trainer assigned by instructor.
2. Perform preoperational checks for:
   - a. Frayed or loose wiring.
   - b. Refrigerant line connections for security of connections.
   - c. Master switch for off position.
   - d. Clearance of all obstructions.
3. Operational safety checks.
   - a. Wear goggles while connecting gages, and adding refrigerant.
   - b. Install manifold gages.
   - c. Place suction and discharge service valves in gage position and open king valve.
   - d. Observe manifold gage assembly for proper operating pressure.
4. Turn thermostats to their coldest position.

   NOTE: This keeps the solenoid valves in the OPEN position.
5. Service the system for operation.
6. Adjust the EPR valves and motor control for desired box temperatures.
   - a. Box #1 ____________ °F
   - b. Box #2 ____________ °F
   - c. Box #3 ____________ °F
7. Operate the trainer.
8. Have the instructor check your trainer as it cuts out at designated temperature settings.

9. Postoperation checks.
    a. Disconnect electrical supply.
    b. Pump system down, using proper procedures.
    c. Use goggles while backseating service valves and remove manifold gage line.
    d. Check all switches for OFF position.
10. Have instructor check your work.

Checked by ______________________
(Instructor)

MULTIPLE COMPRESSOR SYSTEMS

OBJECTIVE

1. To identify system's components,
2. To trace refrigerant and electrical flow through the system,
3. To service, adjust and operate a multiple compressor system.

PART I

MULTIPLE COMPRESSORS IN PARALLEL

1. Use the multiple compressor system schematic in figure 7.
3. Write the name and purpose of each unit in the blanks below:

A. ______________________________

B. ______________________________

C. ______________________________

D. ______________________________

E. ______________________________

F. ______________________________

G. ______________________________

H. ______________________________

I. ______________________________

J. ______________________________

3. Draw arrows showing direction of refrigerant flow through the system.

115

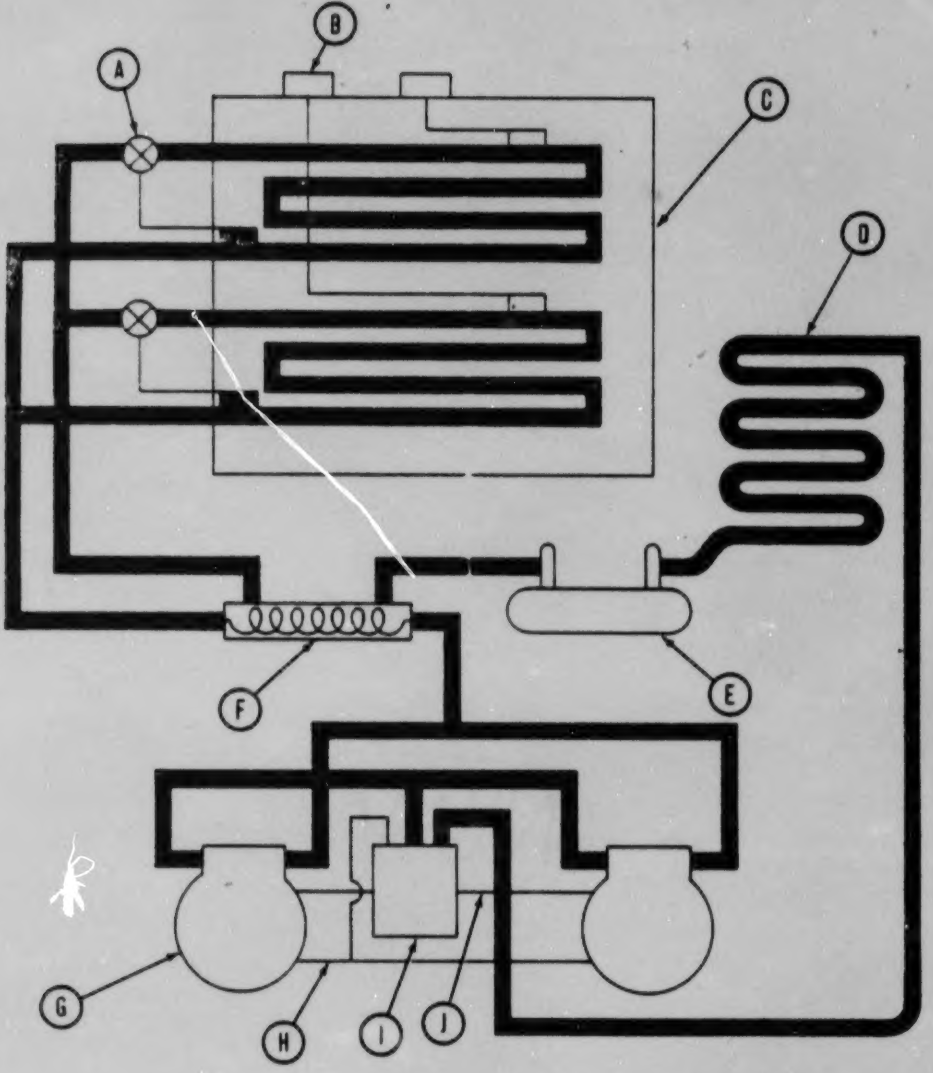
A
B
C
D
E
F
G
H
I
J

Figure 7. Multiple Compressor System Piped in Parallel

116

PART II

MULTIPLE SYSTEM ELECTRICAL DIAGRAM

This project will give you practical experience in tracing the flow of current through the multiple compressors in parallel electrical system.

1. Study the wiring diagram in figure 8 of SG 3ABR54530-VI-1.
2. Start at L_1 or L_2 and draw lines connecting components for correct operation and current flow.
3. Have the instructor check your work.

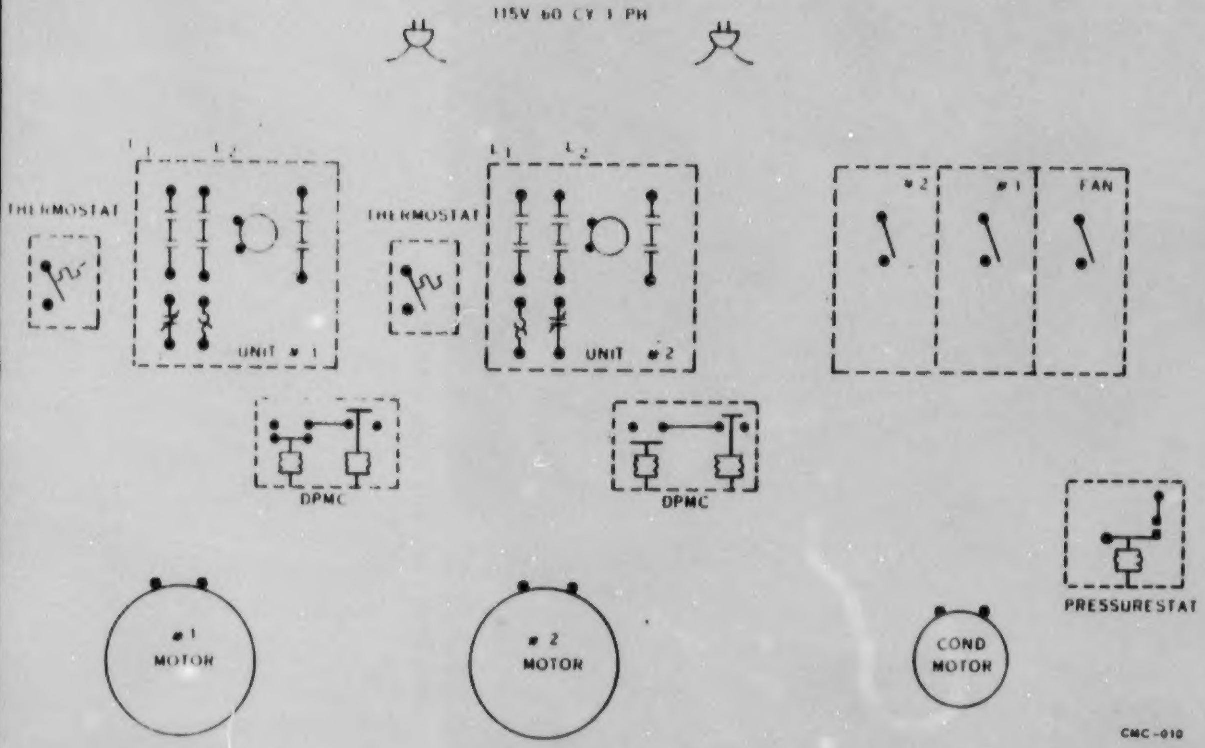
115V 60 CY 1 PH
THERMOSTAT
L1
L2
UNIT # 1
THERMOSTAT
L1
L2
UNIT # 2
# 2
# 1
FAN
DPMC
DPMC
PRESSURESTAT
# 1
MOTOR
# 2
MOTOR
COND
MOTOR
CMC-010

Figure 8. Electrical Components for Multiple Compressors in Parallel

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PART III

MULTIPLE COMPRESSOR TRAINER

Preoperational Checks:

1. Remove all jewelry.
2. Disconnect all power cords.
3. All switches in the OFF position.
4. Check for frayed and loose wiring.

Operational Procedures:

1. Check condenser fan pressuretrol for correct settings.
2. Open equalizer lines shutoff valves.
3. Check DPMC for proper settings.
4. Adjust thermostats to maintain desired evaporator temperatures.
5. To switch lead compressors, readjust thermostat settings opposite as done in step 4.
6. Put on goggles and install manifold gage assembly.

7. Gage service valves and open king valve.
8. Connect power cord to receptacle.
9. Turn on all switches.
10. Observe manifold gage assembly for proper operation.
11. Check sight glass for bubbles.

Postoperation Checks:

1. Close king valve.
2. After unit is pumped down, remove manifold gage assembly.
3. Turn off all switches.
4. Disconnect power cord.
5. Return all equipment to its proper place.

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PART IV

COMPOUND SYSTEMS

1. Use the intercooler compound system schematic, figure 9.

2. Identify the units and write their names in the blanks.

   a. ______________________________

   b. ______________________________

   c. ______________________________

   d. ______________________________

   e. ______________________________

   f. ______________________________

   g. ______________________________

   h. ______________________________

   i. ______________________________

   j. ______________________________

3. Tell if the temperature and pressures are high or low in the following st[illegible]ment.

   a. When the refrigerant leaves the first stage compressor its temperature is

      ______________ and its pressure is ______________________.

   b. When the refrigerant leaves the intercooler, will the temperature and pressure be higher, lower, or equal to what they were on entering the intercooler?

      (1) The temperature is ______________________________.

      (2) The pressure is ______________________________.

4. Use arrows to trace the flow of refrigerant through the system.

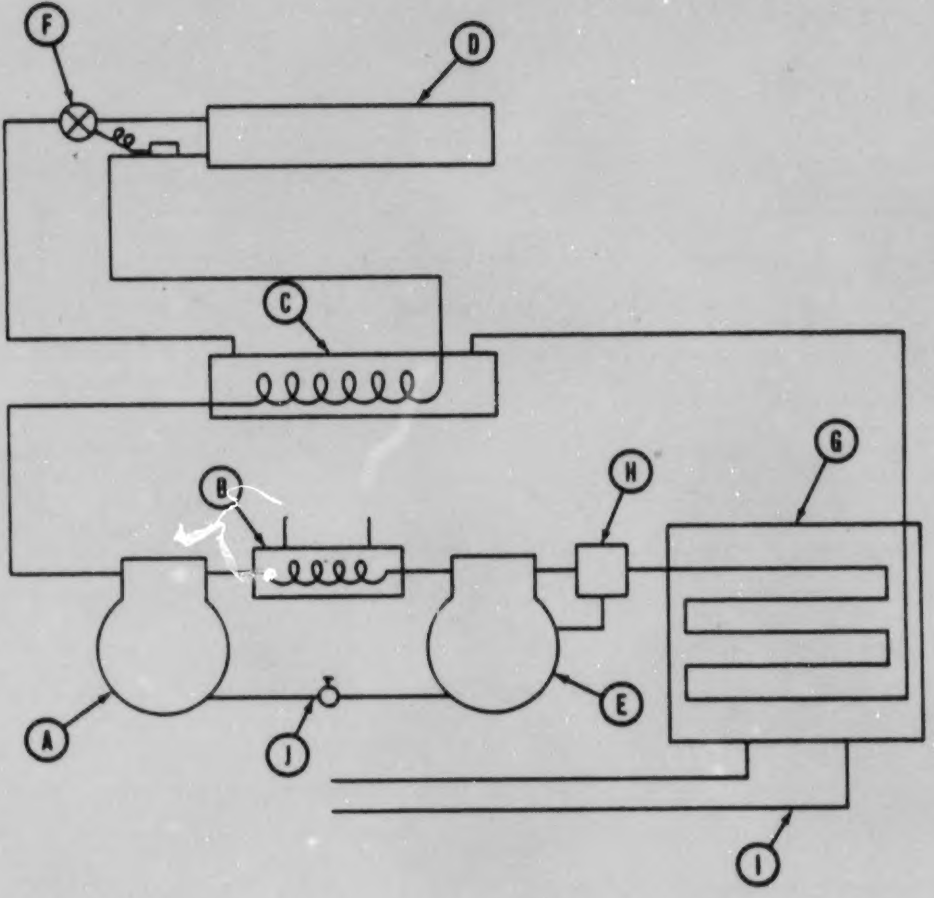
F
D
C
B
H
G
A
J
E
I

Figure 9. Compound System With Intercooler

5. Use the compound subcooler system in figure 10.

6. Identify the components, and write their names and purpose in the blanks.

a. ______________________________

____

b. ______________________________

____

c. ______________________________

____

d. ______________________________

____

e. ______________________________

____

f. ______________________________

____

g. ______________________________

____

h. ______________________________

____

i. ______________________________

____

j. ______________________________

____

7. Use arrows to indicate the direction of refrigerant flow.

123

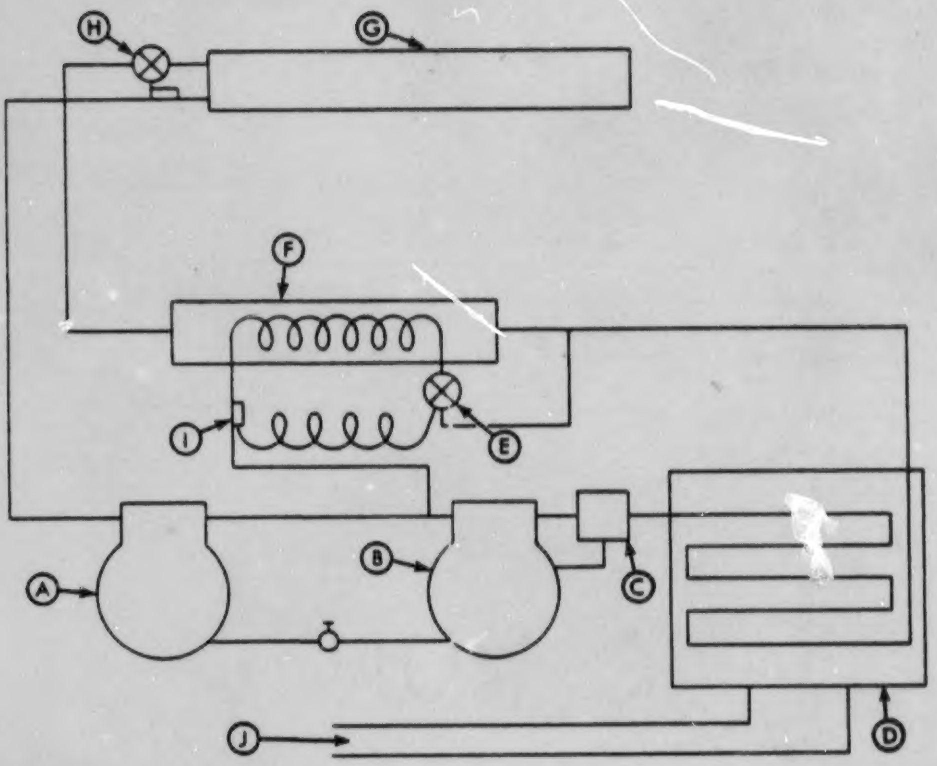
H
G
F
I
E
A
B
C
D
J

Figure 10. Compound System With Subcooler

PART III

CASCADE SYSTEMS

1. Use the elementary cascade system schematic in figure 11.
2. Identify the units and write their names in the blanks.

a. ____________________

b. ____________________

c. ____________________

d. ____________________

e. ____________________

f. ____________________

g. ____________________

h. ____________________

i. ____________________

3. Use arrows to indicate the direction of refrigerant flow.

125

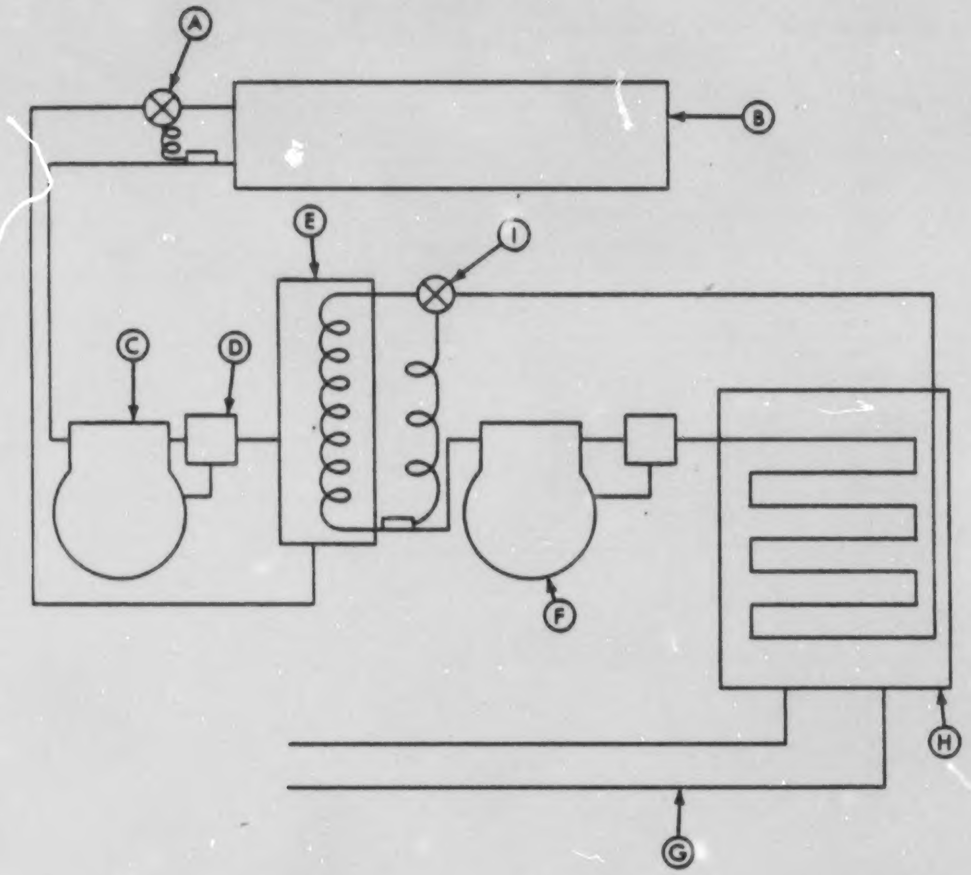

Figure 11. Elementary Cascade System

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4. Using the two-stage cascade system in figure 12

5. Identify the major components and write their names in the blanks.

a. ____________________

b. ____________________

c. ____________________

d. ____________________

e. ____________________

f. ____________________

g. ____________________

h. ____________________

i. ____________________

j. ____________________

k. ____________________

6. Use arrows to indicate direction of refrigerant flow.

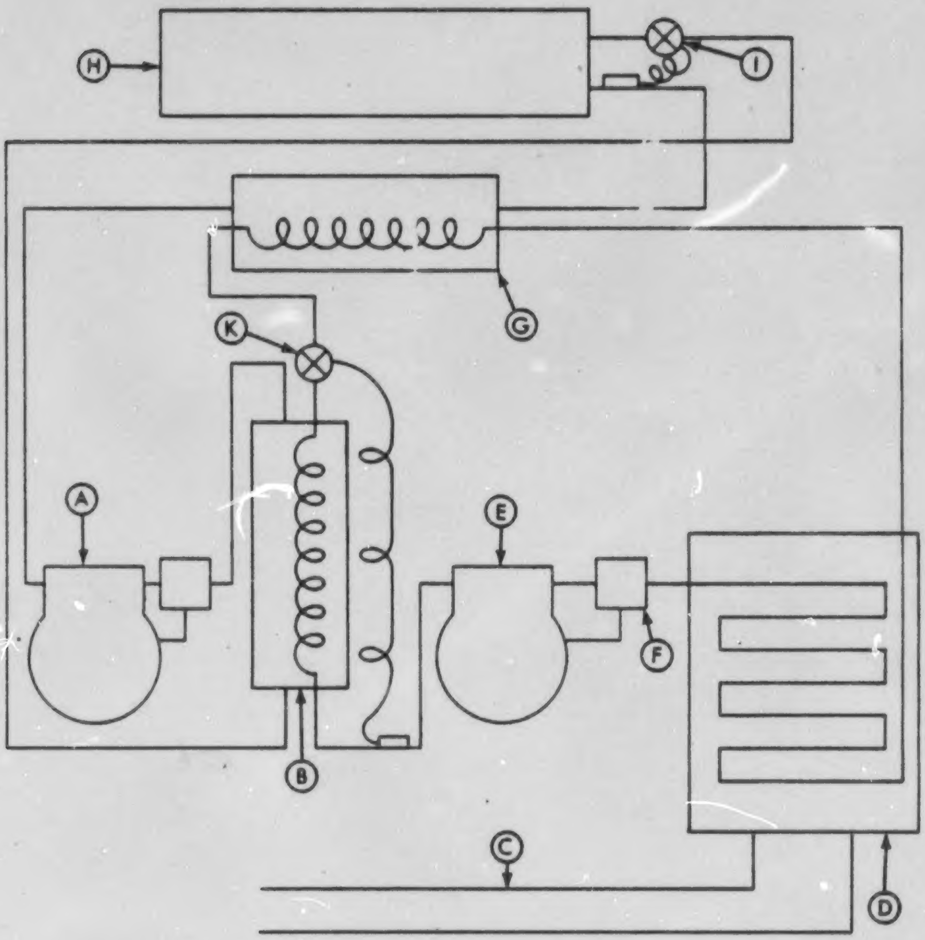
H
I
G
K
A
B
E
F
C
D

Figure 12. Two-Stage Cascade System

EVAPORATIVE COOLING TOWER COMPONENTS

PART I

OBJECTIVE

1. To identify all major system components.
2. Use the schematic of the cooling tower in figure 13.
3. Write the names of the components from the schematic in the blanks below. State their purpose.

	COMPONENT	PURPOSE
a.		
b.		
c.		
d.		
e.		
f.		
g.		
h.		
i.		
j.		
k.		

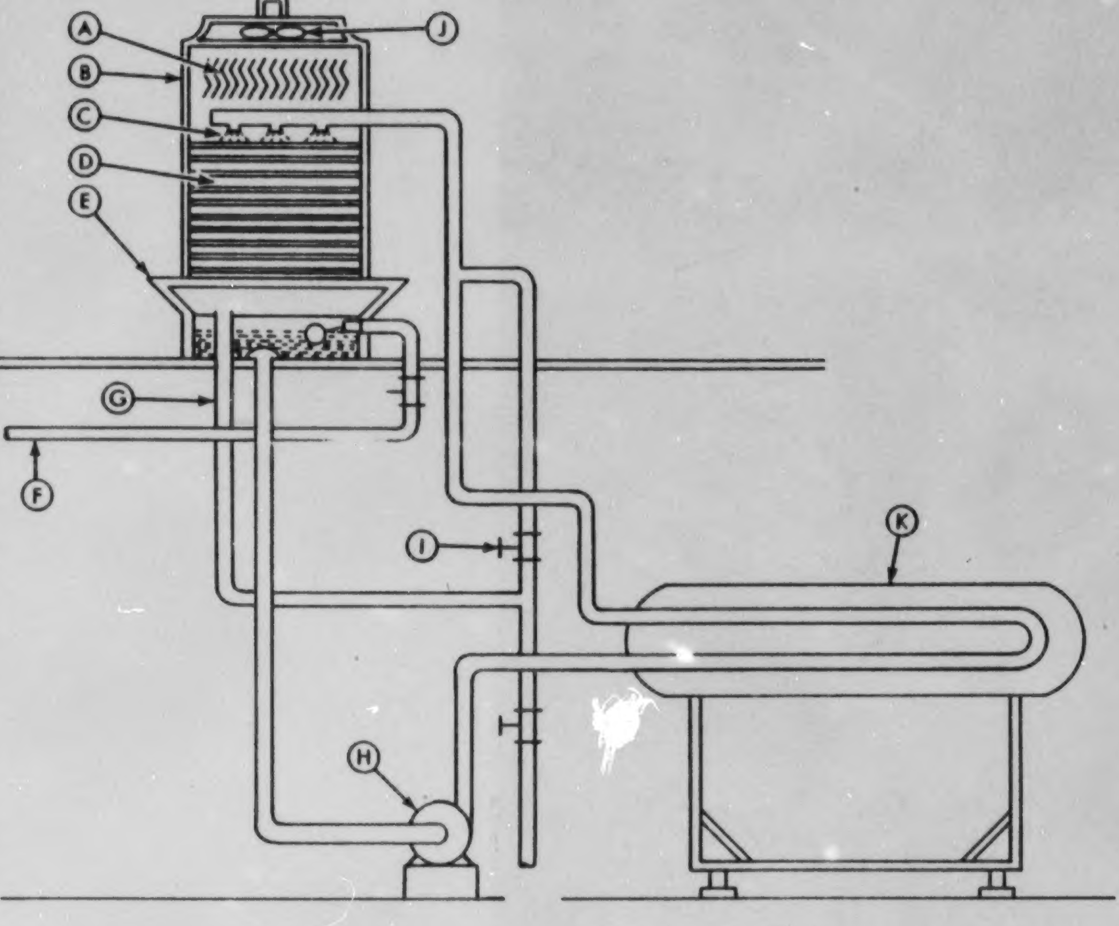
A
B
C
D
E
F
G
H
I
J
K

Figure 13. Evaporative Cooling Tower

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PART II

3. Using figures 14 and 15 indicate the flow of air and the flow of water through the cooling towers.

   a. airflow

   b. waterflow

4. Have the instructor check your work.

Checked by ______________________
(Instructor)

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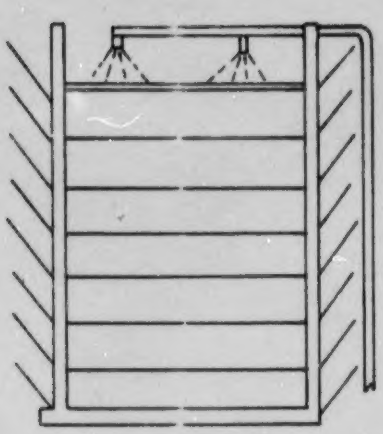

Figure 14. Natural Draft Cooling Tower

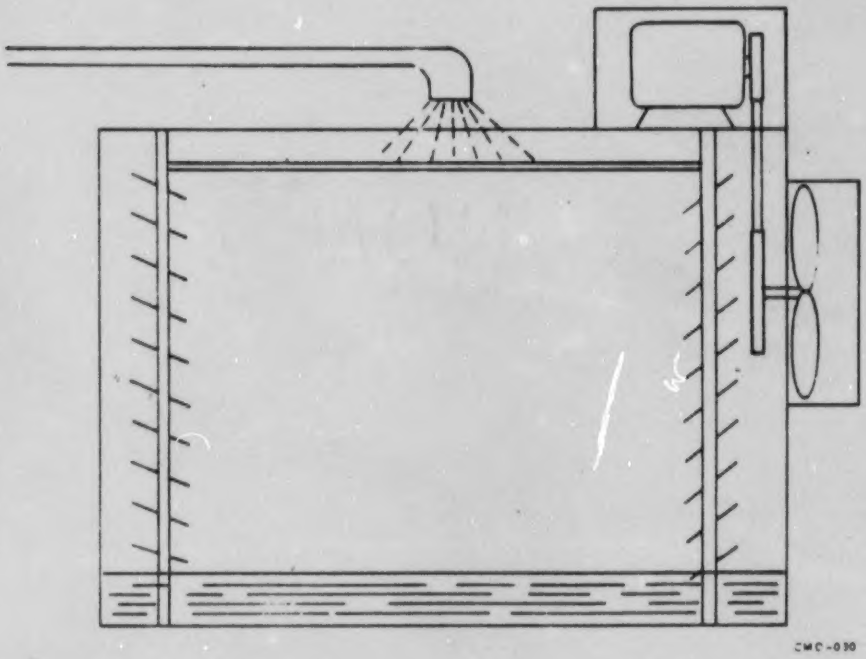

Figure 15. Forced Draft Cooling Tower

BLEED-OFF AND MAKEUP WATER REQUIREMENTS

OBJECTIVE

To determine bleed-off and makeup water requirements.

Complete the sentences below with the most correct response from information in the Study Guide.

1. For most systems the bleed rate should be __________ gallons per hour per ton.
2. Makeup water replaces the water that has been lost due to ______________
   ____________, ________________ and ______________________
3. The ______________ valve is installed in the water makeup line to start and stop the flow of makeup water.
4. Leave a clearance between bleed-off line and drain, so a ______________
   ______________ can be used to measure the bleed rate.
5. Bleed rate can be measured by determining the ____________________
   ____________________ it takes to fill a ____________________
6. Bleed rate in gallons per hour equals ____________________ divided by
   the ____________________ required to fill a ____________________
7. The bleed line must be located higher than the water level in the sump to
   prevent the water from ________________________ out when the system
   ________________________ running.

Checked by ____________________
(Instructor)

EVAPORATIVE COOLING TOWER CAPACITY CONTROL

OBJECTIVE

To trace the flow of water through the cooling tower capacity control system.

Complete the statements with the correct words in the blanks from the information on capacity control in the study guide.

1. The modulating valve is operated by a ________________________ electric motor and thermostat.
2. When the water temperature decreases, the valve ____________________ the waterline from the tower to the ____________________________________
3. When the condenser water temperature rises to the cut-in setting on the thermostat bypass portion of the valve ____________________________________
4. The cooling tower fan is cycled by a pressurestat that is connected to the compressor ____________________ line.
5. When the discharge pressure increases, the ______________________ will cycle the fan to the ________________ position.
6. When the discharge pressure decreases to the pressurestat setting, the fan is cycled ________________________.
7. The modulating dampers are located in the tower fan ______________ airflow.
8. A remote bulb sensing element is installed in the ________________________ of the cooling tower.
9. When the condensing pressure increases, the _________________ temperature increases.
10. The thermostat sends a signal to the _______________ to open the dampers.

Checked by ________________________
(Instructor)

IDENTIFICATION OF CENTRIFUGAL WATER PUMP COMPONENTS

OBJECTIVE

To list the names and give the function of each numbered portion of the centrifugal pump.

Locate each numbered item on the pump trainer. List the proper nomenclature and function.

	NOMENCLATURE	FUNCTION
1.		
2.		
3.		
4.		
5.		
6.		
7.		
8.		
9.		
10.		

Checked by ______________________
(Instructor)

ALIGN FLEXIBLE COUPLING USING DIAL INDICATOR

OBJECTIVE

Using a centrifugal pump trainer, dial indicator and accessories, align the flexible couplings to given conditions.

NOTE: There are two types of misalignment encountered with flexible couplings: angular misalignment in which the shafts are not parallel, and parallel misalignment where the shafts are parallel but not on the same axis. See figure 16.

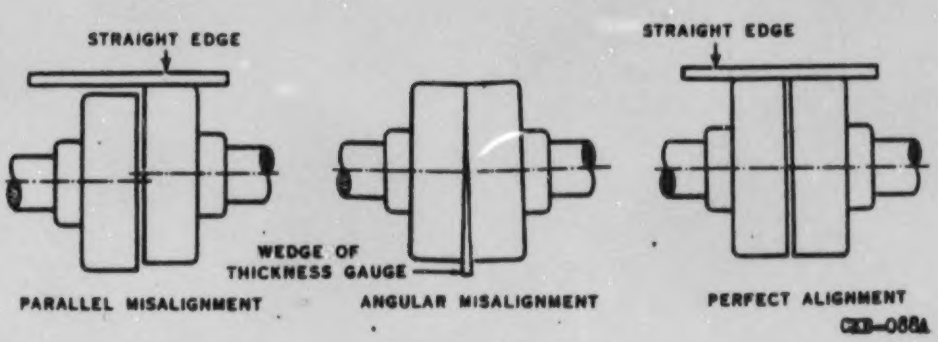

Figure 16

PROCEDURE

1. Instructor will issue dial indicator and accessories.

NOTE: The dial indicator is a precision, delicate instrument. Do not abuse by rough handling or mistreatment.

2. Use trainer assigned by instructor.

3. To check angular alignment with a dial indicator, clamp the dial indicator to the pump coupling half so that the ball of the indicator just rests on the face of the motor coupling half. A chalkmark should be made at the point where the ball contacts the coupling half. Both the pump shaft and motor shaft should be rotated an equal amount so that the reading is taken at all checkpoints with the ball on the chalkmark (B in figure 17).

4. Total runout reading must not exceed 0.015.

5. Insert shims as required to attain satisfactory runout.

6. To check parallel alignment with the dial indicator the ball should rest on the outer edge of the motor coupling half as indicated by "A" in figure 17. A chalkmark should be made at the point of contact, and the shafts rotated equally so that the reading is taken with the ball on the chalkmark at all checkpoints.

7. Total runout must not exceed 0.015.

8. Insert shims as required to attain satisfactory runout.

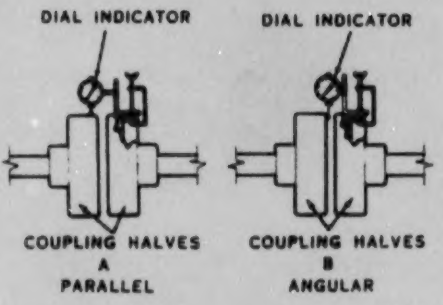

Figure 17

NOTE: Any adjustment to correct one direction of alignment may affect the other direction. Therefore, it is necessary to recheck both angular and parallel alignment after each adjustment.

9. After the unit has set, alignment of the unit should be checked and the foundation bolts torqued.

10. Have instructor check your work.

11. Return dial indicator and accessories to instructor. Instrument will be checked for abuse and mishandling.

Checked by ____________________
(Instructor)

STUDY GUIDE 3ABR54530-VI-5 and 6

Department of Civil Engineering Training

Refrigeration and Air-Conditioning Specialist

WATER CONDITIONING AND ABSORPTION AIR-CONDITIONING SYSTEM

January 1975

SHEPPARD AIR FORCE BASE

11-8

Designed For ATC Course Use

DO NOT USE ON THE JOB

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Refrigeration and Air-Conditioning Specialist

(Days 51-55)

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This supersedes SGs 3ABR54530-VI-5 and 6, and WB 3ABR54530-VI-5-P1 thru 6-P7, 28 October 1973
Copies of the superseded publication may be used until the supply is exhausted.

Department of Civil Engineering Training
Sheppard Air Force Base, Texas

SG 3ABR54530-VI-5
22 January 1975

WATER CONDITIONING

OBJECTIVE

This study guide will help you in learning:

- Basic principles of chemistry and chemical processes.
- Problems encountered when using water for cooling purposes.
- Causes and effects of scale and corrosion.
- Methods and procedures for treating scale, corrosion and algae.
- To identify laboratory equipment.
- To perform chemical experiments to determine the types and amount of contaminants in a sample of water
- To test phosphates as used in cooling towers.

INTRODUCTION

Corrosion is the destruction of metal by chemical or electrochemical action. Rust is a form of corrosion. All metals containing iron will rust if exposed to the effects of air and moisture. Water increases the corrosion or rusting process.

Scale is the residue or deposits left by water. This can be demonstrated by placing some water containing minerals in a pan and boiling away the water. The minerals will be left in the pan. If this process is continued several times, the pan will become covered with a coat of these minerals. These minerals are called scale.

Algae is small microscopic plant and animal life that forms and grows in water. Algae if uncontrolled can become a big problem in water towers, tanks, piping, pumps, and condensers.

LABORATORY SAFETY

Before making chemical analysis of water samples, you must be aware of the safety practices that apply to chemical laboratories.

- Never mix chemicals haphazardly.
- Do not taste or drink chemicals.
- Use smallest amount of chemicals necessary to get desired results.
- Perform experiments at arm's length.
- Smell gases slowly.
- Have plenty of ventilation.
- Always add acid to water, not water to acid.
- Keep working area and equipment clean.
- Use face shields, rubber gloves, and aprons when using scale cleaner.
- If hands or skin burn, flush them with plenty of water.
- Label all chemicals and tests.
- Do not close containers that are heating.

The work of a Refrigeration Specialist in water treatment can be safe if the specialist will use a few simple precautions in the handling and mixing of chemicals, and the handling of glassware and operating equipment. Accidents just do not happen; they are caused by unsafe acts or conditions. The skilled operator knows his chemicals, the proper method of mixing them, the correct manner of operating his equipment, and the importance of keeping his mind on his work. The last is very important because many times after an accident, the victim has remarked, "I wasn't thinking."

Handling Acids and Bases (Alkalies)

Acids and bases (alkalies) can cause severe burns when they come in contact with the skin. When handling chemicals, never put your hands to your eyes or face without first washing them. The skin tissue of your face is more sensitive than that of your hands and is more easily irritated. Rubber gloves must be worn when handling concentrated acid to protect your hands. To protect your clothes you must wear a rubber apron. Before using these protective devices they should be inspected to assure they will afford the protection for which they are intended.

When mixing concentrated acids with water, the acid should be slowly poured into the water and the solution should be constantly stirred with a glass stirring rod to prevent a concentration of the acid in a small area of the water. Failure to follow this procedure may result in the acid boiling and splattering the surrounding area, causing severe burns to the operator. NEVER POUR WATER INTO ACID. If you get

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a spray of acid in your face or eyes, don't put your hand to your face. Flush the affected area with a lot of water as fast as possible and then seek a doctor for further treatment. Anytime you are using acids, you should have a container of water and sodium bicarbonate (baking soda) available to neutralize the acid in case of an accident.

A few drops of acid on the hands may not cause any discomfort, but if this acid is rubbed into the eyes it could cause blindness.

Cut From Glassware

Before using any glass laboratory equipment, the article should be checked for cracks and rough edges. The rough edges can develop into cracks and when a stopper is applied the glass may break and spill its contents all over the lab table and surrounding area.

Heating Liquids

When heating a liquid in a beaker or flask, always apply the heat gradually. A large amount of heat concentrated in a small area can set up a strain that might cause the beaker or flask to crack.

LABORATORY EQUIPMENT

The refrigeration specialist must become familiar with the types and functions of standard laboratory equipment if he is to test and treat water properly.

Reagent

A reagent is any substance which, because of its part in certain chemical reactions, is used in detecting, examining, or measuring other substances. Standard soap solution is a reagent that you will use in performing a hardness test.

Burette

Burettes are used in the laboratory to measure solutions and reagents. (See figure 1. You will use a burette to measure standard soap solutions.

Beaker

A beaker is a large glass container used when mixing or testing solutions. (See figure 2.

Funnel

The funnel (figure 2) is used for pouring liquids and filtering solutions.

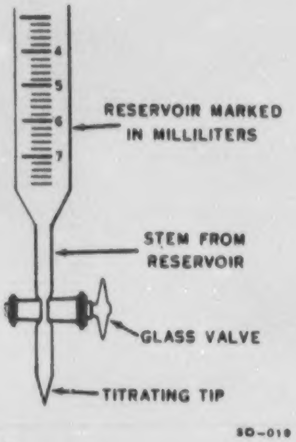


Figure 1. Burette

Filters

Filters are used to separate solids suspended in liquids. To prepare a filter, fold a filter paper first in halves, then into quarters. (See figure 2). Open it with three flaps on one side and one flap on the other so it will fit the funnel.

Graduated Cylinder

The graduated cylinder (figure 2) is used to measure liquids. It is usually graduated in milliliters.

Flask

A flask is a narrow-necked vessel used for various purposes in a laboratory. (see figure 2).

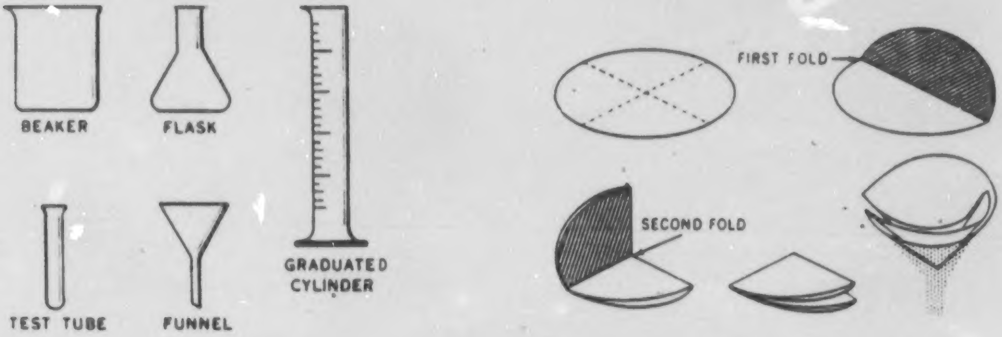


Figure 2. Laboratory Equipment

Care of Test Equipment

In making a number of different tests where various solutions are used, it is necessary to avoid contamination. Rinsing prior to use and careful cleaning of equipment after the tests have been completed assures accurate results.

Burettes should not be interchanged between standard solutions except in emergencies, and then only after thorough rinsing. Stopcocks should be lubricated with approved stopcock grease at frequent intervals to keep them in good working order.

Expression of Test Results

Listed below are expressions of test results and their meaning.

PARTS PER MILLION (PPM). A part per million is a measure of proportion by weight and is equivalent to a unit-weight per million units-weight. A pound of clay in a million pounds of water is equal to one part per million.

GRAINS PER GALLON (GPG). The grain is the smallest unit in the English system of measurements pertaining to mass (weight). One pound equals 7000 grains. If you wish to convert ppm use the factor: 17.1 ppm equals 1 gpg US gallon.

LITER. The liter is the standard unit of capacity used in the laboratory. It is the volume of 1000 grams of water at 4°C, and is divided into 1000 smaller units called milliliters. Since the weight of a liter of water is 1000 grams, each milliliter of water will weigh 1 gram, and 100 milliliters of water will weigh 100 grams, etc.

COMMON ELEMENTS

ELEMENT	SYMBOL	ATOMIC NO.
Aluminum	Al	13
Calcium	Ca	20
Carbon	C	6
Chlorine	Cl	17
Copper	Cu	29
Fluorine	F	9
Hydrogen	H	1
Iron	Fe	26
Magnesium	Mg	12
Mercury	Hg	80
Oxygen	O	8
Potassium	K	19
Sodium	Na	11
Sulfur	S	16

Table 1. Table of Elements

COMMON CHEMICALS ASSOCIATED WITH WATER TREATMENT

Most of the chemicals that you will be concerned with in this course are listed in Table of Chemicals, Table 2. The formula, chemical name, and common name or usage that will be important to you are included. NaCl for instance, is the chemical formula for table salt. The chemical name for table salt is sodium chloride. Table salt is sometimes used in refrigeration work as a brine.

FORMULA	CHEMICAL NAME	COMMON NAME OR USAGE
Ca	Calcium	Scale forming element
Ca (HCO$_3$)2	Calcium Bicarbonate	Temporary hardness
$CaCO_3$	Calcium Carbonate	Limestone (scale)
$CaCl_2$	Calcium Chloride	Brine
$Ca(OH)_2$	Calcium Hydroxide	Lime (water treatment)
CO_2	Carbon Dioxide	Corrosion helper
Cl	Chlorine	Algae control
HCL	Hydrochloric Acid	Scale cleaner
H_2O	Hydrogen Oxide	Water
Mg	Magnesium	Scale forming element
O	Oxygen	Corrosion helper
K_2CrO_4	Potassium Chromate	Corrosion control
Na_2CO_3	Sodium Carbonate	Soda Ash (water treatment)
NaCl	Sodium Chloride	Brine and Table Salt
NaOH	Sodium Hydroxide	Caustic soda
H_2SO_4	Sulphuric Acid	pH adjustment
Na_3PO_4	Trisodium Phosphate	Surface active agents

Table 2. Table of Chemicals

ACIDS, BASES AND SALTS

Acids, bases, and salts are chemical compounds associated with waters used in refrigeration systems. The early chemists discovered that compounds had distinct tastes. Vinegar and lemon juice had a sour taste so the chemists named them "acids" from the Latin word "Acidus," meaning sour.

The second group of compounds such as caustic soda and lime had a bitter taste. This group of compounds would destroy the sourness of acids and would act as a foundation for the manufacturing or making of the third group. Since they acted as a foundation they were called bases.

The third group of compounds was obtained by mixing a base and an acid together. These compounds had a salty taste and were called salts. When these salts are mixed with water, we call them brines. Table salt mixed with water produces a sodium chloride brine. Cold brines are used in ice plants to circulate around fresh water ice cans to produce ice. Brines are very corrosive to metals; therefore, corrosion inhibitors are employed to reduce corrosion. You will perform antifreeze and corrosion inhibitor tests on brines.

Ethylene glycol, the antifreeze similar to that used in your car, is used in chilled water systems to lower the freezing point of water. These solutions are called brines when used for this purpose. However, chemically ethylene glycol is not a brine.

Tests for Acids

The acids you will be most concerned with are hydrochloric and sulphuric. These acids are shown in Table 2.

A very simple test is to place litmus paper in the acid solution. Acids turn blue litmus paper red. Another test for acids is to check the solution with phenolphthalein ("P" indicator). "P" indicator remains colorless when placed in acids.

Concentrated acids such as scale cleaners are very dangerous and must be handled with extreme care. The use of scale cleaners will be covered at a later time. You are cautioned, however, never to pour water into acid. There is an urge in most students to mix chemicals just to see what happens. Remember Rule One of laboratory safety: NEVER MIX CHEMICALS HAPHAZARDLY. Your first workbook will include checking diluted acid solutions with litmus paper and "P" indicator.

Tests for Bases

Bases are probably not as well known as acids but they are just as important.

Sodium hydroxide is a white, crystalline solid. It is soluable in water, bitter to the taste, feels slippery between the fingers and "burns" the skin. It is known as lye or caustic soda. Next to sulfuric acid, sodium hydroxide is probably the most widely used chemical. It is a very strong base and must be handled with caution.

Bases turn red litmus paper blue. When the pH is above 7.9, bases turn "P" indicator red. Bases are used to neutralize acids.

COLLECTING AND LABELING WATER SAMPLES

Collecting the Sample

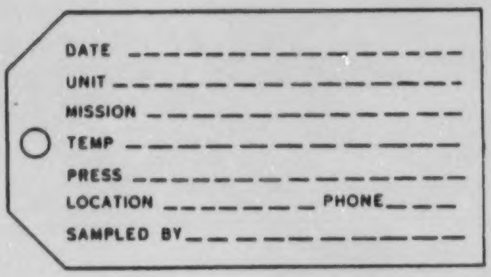
When making field water tests for turbidity, pH and hardness, it is important that your test equipment be clean, and that you obtain a representative sample. There are also times when water problems require other tests such as oxygen, carbon dioxide, chlorides, etc. When these tests are required, special precautions must be taken in collecting and labeling water samples.

The problem in preparing water samples is in obtaining a small amount of water that is representative of the larger amount. If the larger amount of water is uniform or the same throughout, any portion of it would be representative. If it is not, make the sample as uniform as possible by obtaining small portions at intervals so arranged to give a total portion that is representative of the whole. Care must be taken that the sample does not come in contact with anything that will change it. This means that the piping and containers used must not react chemically in any way with the water, and that the sample, after drawn, does not come in contact with the atmosphere because the atmosphere contains many gases and solids that are readily attracted to and dissolved by water.

Labeling the Sample

Water samples are practically useless unless they are properly identified. Many times samples lose their identity in transporting from the point of collection to the testing laboratory. If the containers are properly labeled there is less chance for any mix-up in the resulting analysis. Control would be lost if an operator was instructed to treat lake water based upon a sample taken from a deep well. Properly labeled water samples also aid the chemist in filling out his reports when he has finished testing the water.

The label used on the sample container is usually your own design. Some use tags that are attached to the container by pieces of masking tape or rubber bands; others use 3 x 5 inch gummed labels. The information contained on the label also varies, depending upon the needs of the chemist or installation. Generally the date, unit, specific mission, temperature, pressure in psi, location, phone and by whom samples were collected are recorded on the label. Figure 3 shows a typical label.



DATE ________________
UNIT ________________
MISSION ________________
TEMP ________________
PRESS ________________
LOCATION ________ PHONE ____
SAMPLED BY ________________

Figure 3. Sample Label Tag

TESTING FOR pH

Just as a thermometer measures the intensity of heat, pH measures the intensity of an acid or base in solution. pH means potential hydrogen; a hydrogen atom that has lost its electron (H+); a positive hydrogen atom; a positive hydrogen ion. Where many hydrogen atoms lose their electrons, the water solution containing these hydrogen ions becomes very aggressive; so aggressive, in fact, that the water will eat metal right off iron pipes. This aggressive water is acid in nature.

pH determines the degree of acid or base in solution. As we explained earlier, with litmus paper and "P" indicator we can determine whether a solution is acid or base, but we cannot determine the degree of intensity. With pH comparators, we can determine not only the nature of the solution but also the intensity of acid or base. Acids contain more hydrogen ions (H+) than hydroxyl ions (OH-) and range in pH from 6.9 to zero. Bases contain more OH- ions than H+ ions and range in pH from 7.1 to 14.

Pure water is made up of H_2O molecules but also contains H+ ions and OH- ions in equal amounts. The pH of pure water is 7.0 which is neutral; neither acid nor base. When there are impurities in water, usually this balance is disturbed and there is more H+ or OH-. This causes the water to be acid or base. Going a step further, acids can be identified as those substances which, when dissolved in water, increase the hydrogen ion (H+) concentration; bases as those substances which, when dissolved in water, increase the hydroxyl (OH-) ion concentration. HCL is an acid. NaOH is a base.

It has been found that the hydrogen and hydroxyl ion concentration of pure water is 0.0000001 gram per liter. This is equal to $1/10^7$ grams per liter and a pH of 7.0. If the hydrogen ion (H+) is increased, say, 10 times, there would then be 10 times 0.0000001 gram per liter or 0.0000001 = $1/10^6$ grams. The pH value of the water would then be expressed as 6.0. A pH of 5.0 is 10 more times more acid than a pH of 6.0.

The relation between H+, OH-, and pH values is shown in figure 4.

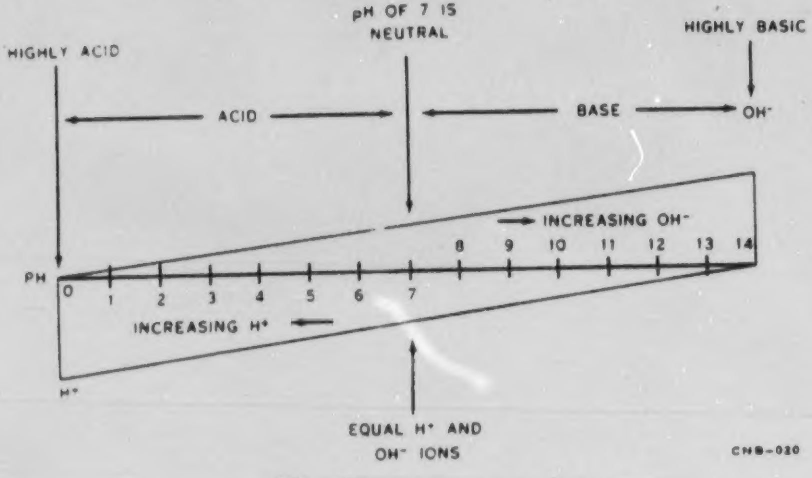


Figure 4. pH Relationship

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Note that as the pH value decreases, the H+ increases and the OH- decreases. At zero pH, the H+ is at maximum and OH- at minimum. For basic waters the reverse is true. As the water becomes more basic, the concentration of OH- increases but the H+ decreases. At pH 14, OH- is at maximum and H+ is at minimum.

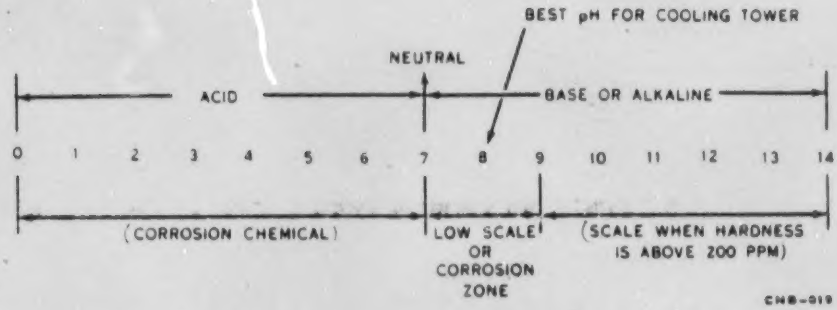
BEST pH FOR COOLING TOWER
NEUTRAL
ACID
BASE OR ALKALINE
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
(CORROSION CHEMICAL)
LOW SCALE OR CORROSION ZONE
(SCALE WHEN HARDNESS IS ABOVE 200 PPM)
CHB-019

Figure 5. pH Adjustment

CORROSION CONTROL

Corrosion is destruction of metal by chemical or electrochemical reaction. (See figure 6.)

Chemical Corrosion

Corrosion caused by chemical reaction occurs when the pH of the water solution is below 7.0. During chemical attack, the metal dissolves into the acid solution. Metal is eaten away uniformly. If corrosion is not arrested, failure of the pipe or tubing will take place.

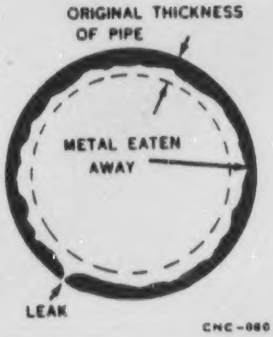
ORIGINAL THICKNESS OF PIPE
METAL EATEN AWAY
LEAK
CNC-080

Figure 6. Corrosion

The pH requirement for minimum corrosion or scale formation in chilled and cooling water systems is between 7.0 and 9.0. Steam boilers require a pH between 10.0 and 12.0.

Electrochemical Reaction

Electrochemical action is similar to the reaction which takes place in the battery of your car. When two dissimilar metals are in contact, such as brass and steel, a cell results. (See figure 7.) Metal will be removed from one and will either go into solution or be deposited upon the other. Nonuniform corrosion is produced by electrochemical cells.

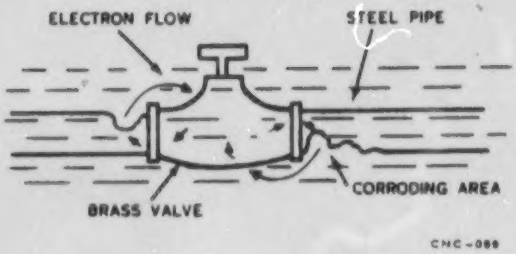

Figure 7. Cells Created by Dissimilar Metals

Ac electrical equipment should not be grounded to water pipes that show signs of electrochemical corrosion, as this makes more active cells with a resultant increase in the corrosion rate.

General Methods of Preventing Corrosion

Various methods may be employed to prevent corrosion. Oxygen and carbon dioxide may be removed from the water by mechanical or chemical means. Chemicals are added to the water to form protective films on the metal and direct current is impressed on the metal to prevent cell type corrosion. As Refrigeration Specialists we will be primarily concerned with chemical treatment.

Corrosion Prevention by Chemical Treatment

The most common chemicals used by the Refrigeration Specialist to control corrosion are chromates and polyphosphates.

CHROMATES. Chromates are very seldom present in untreated water, however, they may occur as a result of industrial waste contamination. Chromates are among the most widely used chemicals for control of corrosion in cooling systems. It is important that tests be made to regulate the proper concentration of chromate necessary for satisfactory corrosion control. The most commonly used chromate salts are sodium and potassium chromate and dichromate. The chromates are alkaline while the dichromates are acidic. Chromates are anodic inhibitors and can intensify pitting if used in insufficient concentration to completely stop corrosion attack. High chloride concentrations interfere with the development of a protective film by chromates.

Since chromates have a toxic effect, chromate salts are not suitable for use in drinking water.

Chromates may have an irritant action if exposure to the skin is prolonged. When working around chromates, any exposed area of the body should be washed with soap and water. Special protective creams and liquids have been developed to aid in the prevention of skin irritation due to chromate toxicity.

Optimal dosage of chromate depends on the character of the water and of the system: in general, however, excellent results are obtained with a maintained concentration of approximately 250 - 300 parts of chromate per million parts of water. Guessing at the concentration of treatment in the water is not satisfactory. Field tests must be made to make sure that the required amount is present. You will perform field tests on chromate concentrations during practical work.

Chromates are used primarily in chilled waterlines and ice plant brines. For cooling towers the use of polyphosphates is less expensive.

POLYPHOSPHATES

Polyphosphates, such as Calgon, Nalco 918 and similar compounds, are used for the prevention of corrosion. Corrosion inhibition is caused by the absorption of the phosphate or one of its complexes on the metal forming a protective film. The rate of supplying the phosphate to the metal is the important factor rather than its concentration in the water.

For initial installation, it is desirable to have a high feed (10 ppm) to form a film as quickly as possible. As soon as the protective film has formed, the dosage may be reduced to 2 to 4 ppm depending on what is required to maintain a constant film on the metal. Phosphates are useful in a pH range of 5.0 to 8.0. However, best results are obtained when the pH ranges from 6.5 to 7.0. In beginning the treatment of corroded pipe systems, difficulty is often experienced with the staving off of corrosion products due to phosphate treatment. Therefore, care is required to avoid problems. Chemical feed is usually by solution feeders identical to hypochlorinators. Since polyphosphate solutions support bacterial growth, a small amount (2 - 3 ppm residual chlorine) of hypochlorite should be used in the solution to avoid contamination.

ALGAE

Algae are slimy living growths of one cell animals and plants. They may be brought in by birds or high winds. Algae thrives in cooling towers and evaporative condensers where there is abundant sunlight and high temperatures to carry on their life's processes. Algae formations will plug nozzles and prevent proper distribution of water which will in turn cause high condensing pressures and lowered efficiencies. Algae prefers water with high temperatures and pH range between 7.0 and 9.0.

Chlorine Test

Secure a sample of water to be tested. Fill both of the standard comparator tubes to the 15 ML mark with test sample, and place them in the comparator tester. Using the graduated dropper, add 0.75 ML of ortho-tolidine solution to the left tube. Insert chlorine color disc and rotate until there is a match in color. Read the results and record directly.

SCALE

Causes of Scale

Scale is a white deposit consisting of compounds of calcium and magnesium. Scale on the inside of piping such as water-cooled condensers presents a serious problem to the Refrigeration Specialist because it reduces the efficiency of a condensing unit. Scale formation in condenser tubing is shown in figure 8.

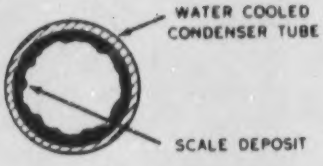
WATER COOLED CONDENSER TUBE
SCALE DEPOSIT

Figure 8. Scale in Water Cooled Condenser

Sludge is a soft scale type material that is easily removed when it forms. If not removed, it may harden into a hard scale.

Scale Forming Waters

Pure water is seldom if ever found in nature. Impurities are picked up by water as indicated in figure 9.

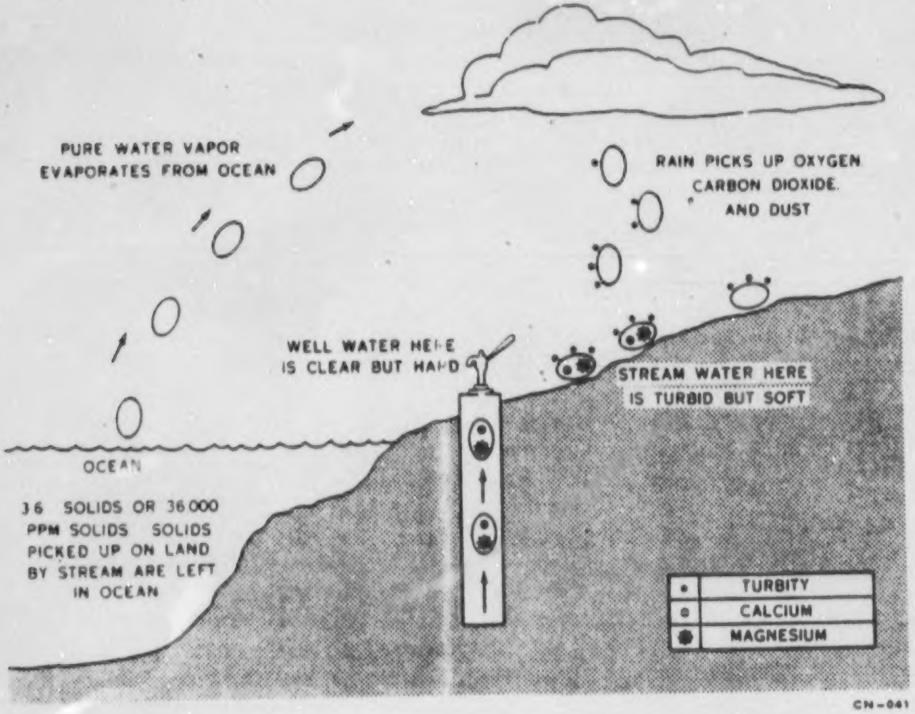
PURE WATER VAPOR EVAPORATES FROM OCEAN
RAIN PICKS UP OXYGEN CARBON DIOXIDE AND DUST
WELL WATER HERE IS CLEAR BUT HARD
STREAM WATER HERE IS TURBID BUT SOFT
OCEAN
3.6 SOLIDS OR 36,000 PPM SOLIDS SOLIDS PICKED UP ON LAND BY STREAM ARE LEFT IN OCEAN
● TURBITY
○ CALCIUM
✱ MAGNESIUM
CN-041

Figure 9. Impurities in Natural Waters

Pure water evaporates from the ocean and other large bodies of water. This evaporated water vapor forms into clouds which are moved inland by winds. Water vapor is released from clouds as rain. Pure rainwater on its path to earth picks up impurities such as oxygen, carbon dioxide and dust.

As the rain falls on the land, some of it travels rapidly on the surface and some of it goes into the ground. In both cases solids are picked up by the water. In figure 10, the water in the stream is shown to have picked up turbidity and also calcium and magnesium minerals. The calcium and magnesium content is less than 100 ppm ; however, because the stream is near the source of rainfall, some streams have very hard water. This means that the calcium and magnesium concentration is above 100 ppm. The water in Wichita River is about 900 ppm hardness.

Some of the water that goes into the soil travels slowly through various types of formations. The further the water travels, the more minerals the water picks up, but the more turbidity it loses. The water below the surface in figure 9 is shown traveling underground. As it travels it loses turbidity (solids in suspension) but it gains calcium and magnesium compounds (solids in solution). When this water is pumped out of a well, the water is clear but hard.

The water used at Sheppard Air Force Base is surface water that has been filtered and treated by the city of Wichita Falls, and the water used in Burkburnett, Texas, is clear well water. The treated water used at Sheppard is much less scale forming than that used at Burkburnett because the concentration of hardness minerals is less.

Scale Formation

When water containing even a small amount of hardness is used in cooling towers as make-up water, scale may form on heat transfer surfaces. As stated in the introduction, when water evaporates, the hardness increases. Assume a cooling tower using makeup water has 80 ppm hardness. By adjusting the bleed-off of two gallons per hour (g. p. h.) per ton of refrigeration, the concentration of hardness solids will double. This means that the recirculating water will contain 160 ppm; not scale forming. Suppose, however, that some one pinches down on the bleed-off. The concentration of hardness, known as cycles of concentration, may go to 3. Then the recirculating water will be 80 x 3 equals 240 ppm. Since scale starts at about 200 ppm heat transfer surfaces may pick up scale.

Besides evaporation and concentration, scale forms because calcium and magnesium compounds have a reverse solubility factor. To explain reverse solubility, suppose we take a glass of water at 80°F and dissolve sodium chloride (table salt) in the water. Soon we would saturate the water with salt; no matter how hard we stirred, we could not get any more salt to go into the solution. Now let us heat the water to 100°F. Sodium compounds have a direct solubility; so by stirring, we can get more salt to go into solution until the solution is saturated at 100°F. Calcium and magnesium saturates a solution in reverse to sodium. A glass of water at 80°F saturated with calcium or magnesium compounds will precipitate some of the compounds when heated to 100°F. In other words as the temperature of the water increases, the solubility of calcium and magnesium decreases.

When calcium and magnesium precipitate on hot condenser surfaces it causes scale.

EFFECTS OF SCALE

Scale is an insulator of heat. Insulating materials similar to asbestos are made of calcium and magnesium compounds. Such materials will prevent the heat of a blowtorch from penetrating them.

Tests have shown that some scales, the thickness of a dime on condenser surfaces, will reduce the efficiency of the condenser by as much as 50 percent.

Scale causes condensing units to operate at higher head pressures. This causes the condensing temperature to become higher which causes even more scale to form.

METHODS OF REMOVING SCALE

It is much easier to prevent scale than it is to remove it, but there will be times when scale removal is necessary. Two general methods are used to remove scale, the mechanical and the chemical method.

Mechanical Method

Scale is removed mechanically by brushing, scraping and grit-blasting. Mechanical methods are very effective on hard, rough surfaces such as evaporative coolers, cooling tower louvers, spray chambers, water pumps, etc. On soft copper and brass surfaces, however, the mechanical method may cause scratches, cuts and nicks which makes a good starting point for scale. In such cases, chemical methods should be employed.

Chemical Method

Chemical methods of removing scale from equipment consist of dissolving scale deposits in a cleaning solution consisting of dilute hydrochloric acid. Whenever possible, commercial inhibitor powder such as antracene, pyridene, or dextrine should be added to the scale cleaning solution. The inhibitor will limit metal corrosion without materially reducing the solvent action on the scale deposit.

A most effective scale cleaning acid solution consists of one gallon of 1.19 specific gravity hydrochloric acid, four gallons of water and 1 1/2 ounces of commercial inhibitor powder. Care should be exercised in preparing the scale cleaning solution to prevent adding water to the acid; the generated heat will cause violent agitation and possible steam explosions. Acid must always be added to water. The usual precautions such as wearing goggles, rubber gloves and aprons should be observed. Do not save or store the spent acid for future use. Prepare a fresh acid solution for each cleaning.

Chemical methods of removing scale deposits provide the following advantages over mechanical methods.

- More complete removal due to ease of fluid penetration.
- The equipment need not be dismanteled since the cleaning solution penetrates wherever water flows.

- The metal surface is left clean of old scale particles which would assist new scale information.
- The metal loss is negligible.

METHODS OF PREVENTING SCALE

There are many methods of preventing scale and every job presents an individual problem. The following methods, in the order listed, are usually the most effective in preventing scale.

- Turbidity Control
- Once-Through Water System
- Bleed-Off Adjustment
- Zeolite Softening
- Total Hardness Test (Scale)
- Surface Active Agents

Turbidity Control

Turbidity means dirty or muddy.

Suspended solids may cause scale on surfaces of equipment in contact with it. The maximum turbidity normally allowed for cooling tower water is 50 ppm.

Once-Through Water

Where abundant supplies of cheap water are available, cooling water may pass through the equipment once and undergo a slight rise in temperature (10°F to 15°F). Little difficulty from scale will be experienced with this method unless the hardness is more than 200 ppm.

Bleed-Off Adjustment

In a system using a cooling tower or evaporative condenser, bleed-off is the best method of preventing scale formation. Bleed-off limits the concentration of hardness in solution in the circulating water. If the bleed-off plugs up, the concentration of scale forming solids will increase rapidly and scaling will result.

With bleed-off set at two gallons per hour (g. p. h.) per ton of refrigeration the cycles of concentration will double. This bleed-off rate (2 gph/Ton) is used when the makeup water ranges from 75 to 100 ppm hardness. Remember scale usually starts when the recirculating waters reach 200 ppm.

Bleed-off should be set at a minimum of one gallon per hour per ton of cooling. If scale forms, the bleed-off should be gradually increased. The maximum bleed-off allowed is 4 gph per ton of cooling. A greater rate would result in a waste of water. If scale does continue to form when bleed-off is set at maximum, then it is necessary to chemically treat the circulating water or soften the makeup water.

Zeolite Softening

If the makeup water is above 100 ppm hardness, it may be necessary to soften the makeup water with a zeolite softener before it can be used in a system. Zeolite softeners are sometimes mistaken for sand and gravel filters. This type softener is not a filter and will be damaged if turbid water is passed through it.

Zeolite softeners exchange the nonscale forming element, sodium, for the scal forming elements, calcium and magnesium. Hardness in makeup water may be softened to near zero hardness with zeolite softeners. When the softener becomes loaded with calcium and magnesium, it may be rejuvenated simply by passing a table salt (NaCl brine) solution through it. (See figure 10).

There are many types and models of zeolite softeners on the market today. They vary in size from the type used to soften water for steam irons in the homes, to the family size zeolite softener, and to very large sizes that will soften water for cities with populations of up to 100,000.

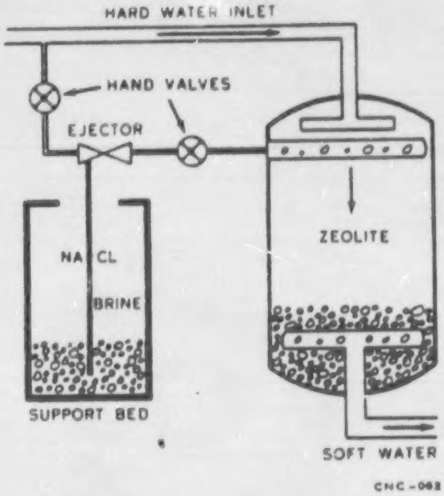

Figure 10. Zeolite Softener

Total Hardness Test

The total hardness test is made to determine the amount of calcium and magnesium compounds that are in solution in water. It is these hardness compounds that cause practically all of the scale problems in water-cooled and evaporative condenser systems. The equipment used to make a hardness test is shown in figure 11.

Soap is used to make a hardness test. Before free suds will form on a water sample, the soap must first neutralize all of the hardness compounds in the water. The higher the hardness test in ppm the harder the water and the greater will be its scale forming tendencies. Have you ever bathed in hard water? The ring around the tub perhaps contained some of your dirt, but most of it was scum caused by the soap neutralizing out the hardness minerals.

A total hardness of 100 ppm is usually the maximum allowed for cooling tower makeup water. Water above 100 ppm is considered hard, whereas hardness below 100 ppm is considered soft.

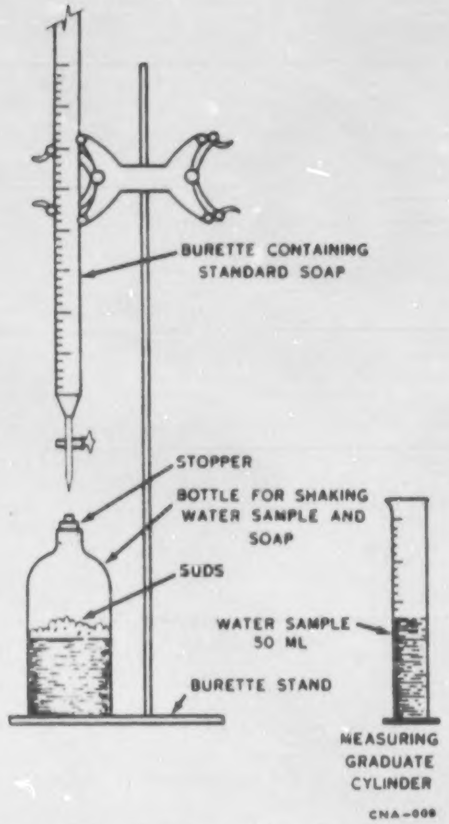
BURETTE CONTAINING STANDARD SOAP
STOPPER
BOTTLE FOR SHAKING WATER SAMPLE AND SOAP
SUDS
WATER SAMPLE 50 ML
BURETTE STAND
MEASURING GRADUATE CYLINDER
CNA-008

Figure 11. Hardness Test Equipment

To make a hardness test, 50 milliliters (ML) of the water to be tested is poured into a bottle. Standard soap solution from a burette is added to the water and the bottle is shaken vigorously. Just enough standard soap is added to cause one inch of suds to form on the water and remain there five minutes. To calculate the total hardness, the ML of soap minus the lather factor multiplied by 20 equals total hardness.

Example: Assume 6 ML of soap was used and the lather factor is 0.3. The lather is the soap required to form one inch of suds when using 50 ML of distilled water. To find total hardness subtract 0.3 from 6.0 and multiply by 20. This is equal to 5.7 x 20 = 114

Formula: Total Hardness = (Total Soap Used - Lather Factor) x 20.

Surface Active Agents

Surface active agents, such as micromets, are polyphosphates which have the property of keeping calcium and magnesium compounds (scale forming) in solution longer than they normally remain. (See figure 12.)

As indicated in the chart, at 100° F, scale starts to form at 200 ppm. When 2 ppm of surface active agents is added to the water, scale does not start forming until the hardness becomes 800 ppm.

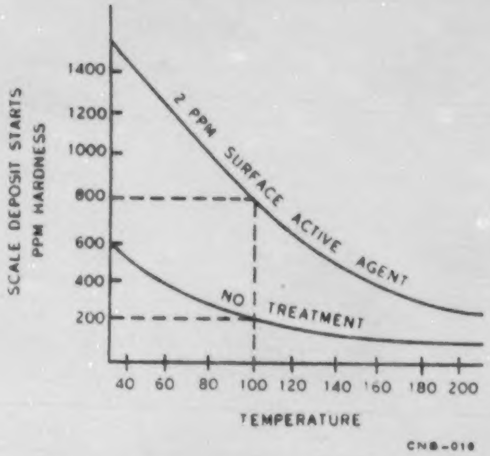

Figure 12. Action of Surface Active Agents

For adequate treatment phosphates must be fed to the tower at a constant rate. Small amounts of phosphates are fed to the water at all times. Nylon mesh bags containing phosphates are placed in the tower, figure 13. As the water flows over the wetted deck it passes through the mesh bag dissolving a small amount of phosphates. Other types of chemical feeders can also be used. If too large a quantity is added at a time calcium phosphate sludge will form.

The amount of phosphate required is dependent upon the bleed rate, hardness, alkalinity, and amount of water in the system. For best results the manufacturer's specification should be followed.

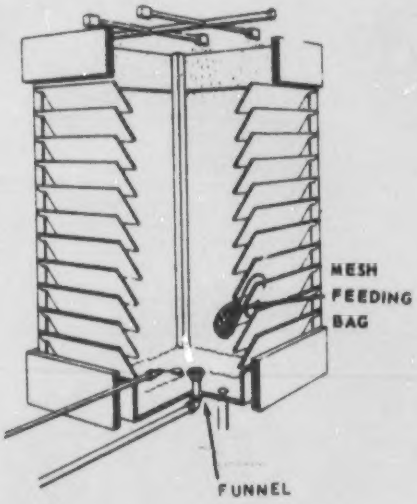

Figure 13. Location of Mesh Feeding Bag

	SCALE	CORROSION	ALGAE
Similar to	Sludge	Rust	Slime
Caused by	Hardness (Ca & Mg) Reverse Solubility Evaporation & Temp Concentration of Hardness	Chemical Action Battery Action Oxygen & Carbon Dioxide Chlorides	One Cell Plants & Animals Sunlight
Effect	White Scale Builds up on pipes High Head Pressures & Temperatures Low Heat Transfer Reduced Efficiency	Eats Away Metal	Plugs Nozzles High Head Low Efficiency
Occurs at pH of	Above 9.0	Below 7.0	pH 7.0 to 9.0 High Temp
Cure	HCL Scale Cleaner Brushing, Scraping and Grit Blasting	Remove Pipe	Clean Manually
Prevention	Turbidity Control Once Through Water Bleed-off 1 to 4 GPH/ton Surface Active Agents Adjust pH (H_2SO_4) to 8.0 Zeolite Softening	Raise pH (NaOH) to 8.0 Chromates Remove Electrical Grounds Paint with Asphalt Varnish	Chlorine Copper Sulfate

Figure 14. Scale, Corrosion and Algae Chart for Cooling Towers and Evaporative Condensers

WATER CONDITIONING

Purpose of Water-Conditioning System

The water-conditioning system is used to keep the concentration of minerals low enough in condensing water and circulating chill water systems to reduce damage or interruption of operation. A good water-conditioning program is as important to a cooling tower system as the water itself. Water conditioning does cost money but it saves money in longer equipment life and more efficient, troublefree service.

Proper treatment of equipment must be provided which will insure the preservation of the various systems. The equipment should be as simple as possible and of the correct type so that treatment can be efficiently and economically accomplished as required. It should be of the quality that it does not break down while it is in service.

Types of Water-Conditioning Systems

There are various types of feeders to admit chemicals, such as phosphates, chromates and acids, to the recirculating water of refrigeration and air-conditioning systems and enclosed chilled water systems.

One type of feeder, the drip or displacement feeder, is placed in the cooling tower. Pot feeders are used for slug feeding of closed systems such as closed heating and chill water systems. Pump type chemical feeders are used on solution tanks especially where the injection is to be made into a pipeline. The chemical briquette feeder is mounted on the outside of the tower. It feeds dissolved cake type chemicals into the sump water. The bypass feeder, similar to the pot feeder, receives water that is bypassed from the circulating water through the feeder tank.

Major Components, Operation and Installations Requirements

The drip feeder can either be gravity or automatic feed. The automatic feeders are calibrated at the factory to insure accurate feeding. The chemical solution is placed in a container above the tower sump. The solution drips into the tower water through a small line from the solution container. The rate of flow is controlled by a needle valve in the feeder line. Some units use a solenoid valve actuated by the recirculating pumps on the unit so the valve will open and close as the pumps start and stop. A constant level reservoir provides steady head pressure to an adjustable needle valve, which is set to drip at a predetermined rate.

The displacement feeder has a second container placed inside the solution container. A small portion of the make-up water is allowed to flow directly into the second container. As the second container fills with water, it forces solution out of the discharge line of the solution feeder.

A very economical method of adding phosphate to the water for conditioning against scale and corrosion is by using a nylon mesh bag. This bag usually comes equipped with a wire hanger for installing it in the water spray, if possible. It is preferred to hang the bag so water will spray over it but it can be placed in the sump. The proper amount of chemicals to place in the bag will be determined by a chart that comes with the chemicals and the size of the system. The chemicals in this bag take up to six months to dissolve.

The pot type feeder is a small cylinder type unit, usually made of clear plastic, which can be mounted on a wall or a stand next to a receiving tank or tower sump. Operating pressure is supplied by the water system from which makeup water is received. All connections are through acid-resistant plastic tubing. This unit has a plastic water operated injector for feeding acid more easily and accurately into an open sump. Makeup water is passed through the injector at a rate not greater than the makeup water requirements. The feeding of acid into the system is controlled by a graduated dial on a valve in the injector. The acid is diluted with water within the plastic body of the injector before it reaches the circulating water. This injector may be used to inject diluted acid through the intake side of a circulating pump, if the pressure is low enough, into a closed system.

The pot type feeder may be used to add liquid or briquette chemicals (figure 15). To fill the tank with chemicals, close the inlet and outlet valves. Then open the bleed, fill and drain valves. When all the water has drained from the tank, close the drain valve and fill the tank with the desired chemicals. To place feeder into operation close the fill and bleed valves. Now open the inlet, outlet and metering valves. Adjust the metering valve to the desired chemical flow while observing the sight indicator. Pressure from the circulating pump forces water up through the inlet valve. Water flows down through the tank taking some of the chemicals with it. The metering valve adjustment determines the amount of chemicals that enters the system on the inlet side of the circulating pump. The treated water goes through the pump where a small portion of it goes back through the chemical feeder. The larger amount goes to the air-conditioning system.

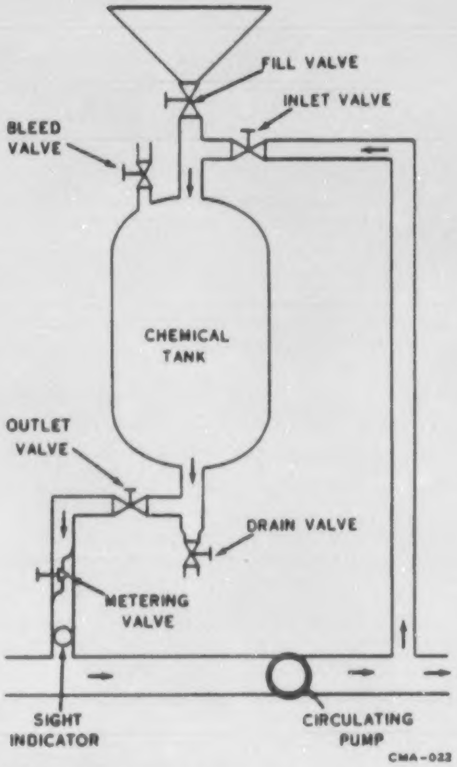

Figure 15. Pot Type Chemical Feeder

An electric pump is required if the acid has to come from a large underground storage tank which is below the water level and the circulating pump sump. This pump is also required when acid is being ejected into a pipeline where the water is under pressure. Diluted acid should be used to reduce the chances of causing corrosion at the point the acid enters the pipe. The rate of flow of this acid should be controlled. A plastic injector tube should be installed so that the acid is fed into the center of the stream away from the walls of the pipe. The container from which the acid solution is pumped must be of corrosion-resistant material, or a steel container with a corrosion-resistant lining. Heavy serviceable plastic containers as well as steel containers, with plastic liners, are available which are suitable for acid solutions. Add the acid slowly to avoid spattering.

The chemical briquette feeder is used to inject phosphate or metaphosphate solutions into the system to control corrosion. Chemicals used by this feeder are obtained in cake or briquette form. These forms have a controlled dissolving rate. The briquette feeder is usually fastened to the outside of the cooling tower above the water sump. The chemicals are injected into the system through a tube in the bottom of the feeder.

Bypass feeders are available for feeding dry chemicals. The feeder is connected to the inlet and outlet of a valve or the inlet and outlet of the circulating pump. A controlled stream of water is bypassed from the circulating water through the feeder tank making a solution of the chemicals and controlling the feeding rate. Bypass feeders are similar to pot feeders, in that both use a needle valve, or similar valve, to control the rate of waterflow through the feeder. In an open pump sump, the inlet for the feeder can be connected to the pump discharge piping and the feeder discharge can flow free into the sump. Chemicals are usually prepared in ball or lump form for bypass feeders.

Servicing Water Conditioning Systems

Each chemical feeder has to be checked periodically. During this check the tanks are refilled with chemicals, the pumps and pipe connections are checked for leakage. The valves are checked for leakage. This determines the condition of the packing and the seating. The motors are checked for cleanliness, terminal security and condition of the wires. All units that have fittings for lubrication are lubricated and checked for freedom of movement. The rate of bleedoff is checked and adjusted if necessary. The plastic needle valves are checked for freedom of movement and adjusted if needed. All metal units are checked for evidence of corrosion.

SUMMARY

Remember most accidents can be prevented. Your part in the safety program is to become familiar with potential accidents and to follow the prescribed rules and precautions to prevent them. Some of the conditions which cause accidents are poor housekeeping, horseplay, improper use of equipment, and nonobservance of rules. The most important rule in the laboratory is never mix chemicals haphazardly.

Laboratory test equipment should be rinsed prior to use to assure accuracy of results.

Most compounds can be classified under one of these headings.

- Acids
- Bases
- Salts (Brines)

Acids turn blue litmus paper red and "P" indicator colorless.

Bases turn red litmus paper blue and "P" indicator red.

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Pure water is seldom, if ever, found in nature. Impure water may cause scale, corrosion, or algae to form in air-conditioning and refrigeration systems using cooling towers and evaporative condensers.

pH is a measurement of the intensity of acid or base in a solution. A pH of 7 is neutral. From 6.9 to 0 a solution is acid. From 7.1 to 14 a solution is basic.

Corrosion is the destruction of metal by chemical and electrochemical reaction. Chromates and polyphosphates are chemicals used to form protective films on the metal thereby preventing corrosion.

Normally three tests will give you the information needed to treat cooling water used in cooling towers and evaporative condensers. These tests are: turbidity, hardness, and pH.

Condensing water systems and recirculating chill water systems are conditioned to prevent the buildup of scale and algae and damage from corrosion. This extends the life of the unit and reduces costs of repairing or replacing parts.

Chemicals are fed into the systems in measured quantities by various types of feeders. When the bleedoff is adjusted properly, the concentration of minerals can be controlled.

QUESTIONS

1. Name five safety practices that apply to mixing chemicals.

2. What are burettes used for?

3. What is a part per million (ppm)?

4. What is the chemical symbol and common name for sodium chloride?

5. What type of injury results from bodily contact with acids and bases?

6. Explain the procedure to be taken in case acid is splashed on the face.

7. What is the effect of an acid solution litmus paper and "P" indicator solution?

8. Explain the meaning of pH.

9. How is corrosion prevented?

10. What is scale?

11. How does scale effect a condensing unit?

12. How is scale removed from a condenser chemically?

13. What is meant by reverse solubility of calcium and magnesium compounds?

14. Name five methods of preventing scale.

15. Explain how surface active agents prevent scale formation.

16. What is turbidity?

17. What is algae?

18. How is algae prevented?

19. What is the purpose of water conditioning?

20. What chemicals are admitted to water by feeders?

21. Where is the briquette feeder mounted?

22. Which is the most economical feeder for adding phosphate to the system?

23. Where is the acid diluted in the pot type feeder?

24. What should be done to prevent acid from causing corrosion at the point it enters a pipe?

25. In what form are the chemicals that are used by the briquette feeder?

26. In what form are the chemicals that are used by the bypass feeders?

REFERENCES

1. AFM 85-18, Maintenance and Operation of Refrigeration, Air Conditioning, Evaporative Cooling and Mechanical Ventilating Systems
2. AFM 85-13, Maintenance and Operation of Water Plants and Systems
3. AFM 85-31, Industrial Water Treatment
4. AFM 127-101, Accident Prevention Handbook
5. Textbook, Handbook on Industrial Water Conditioning

ABSORPTION AIR-CONDITIONING SYSTEMS

OBJECTIVE

To help you learn the scope, application, and maintenance of the lithium bromide absorption air-conditioning system.

INTRODUCTION

The use of aqua-lithium bromide absorption system began in 1945. The principle was a century old; but, until this time, it had never been completely safe, successful or economical.

This simplest of all refrigerating machine uses the cheapest, safest, and most available of all refrigerants--water. Water is stable, nontoxic, low cost, readily available and has 970 BTUs per pound latent heat of vaporization. Its absorbent is--lithium bromide, a salt solution. Most important, large quantities of water are readily absorbed by lithium bromide and easily separated.

The key to understanding the absorption system's operation is to remember the entire unit operates in a deep--vacuum. For water to boil in the evaporator at 38°F a vacuum of approximately 29.65 inches mercury is required. To illustrate the necessity of maintaining these pressures, an increase in pressure of only 0.06 psi in the unit will increase the leaving chilled water temperature 10°F.

This system is used for air conditioning and varies in capacity from three to 5000 tons. The absorption unit is in great demand at the present time in larger installations. The machines low operating cost, dependability, minimum maintenance and space requirement, and long life of serviceability, are the major advantages of absorption systems. However, high initial installation and support equipment costs are a disadvantage.

Operation

The absorption refrigeration unit consists of a generator and an absorber assembly. The condenser and generator are combined in the generator assembly, or upper shell of the unit; while the evaporator and absorber are combined in the absorber assembly, or the lower shell of the unit. The control panel is located on the side of the absorber assembly. The other minor units, such as the absorber sight glass, solution heat exchanger and the solution pump are usually mounted between the supporting legs of the absorption unit.

To understand the operation of the refrigeration cycle, think of two self-contained vessels, one containing the salt solution (which is known as the absorber) and the other containing water (known as the evaporator). Join the two containers as they are in figure 16. Ordinary table salt absorbs water vapor when it is exposed to damp weather. The salt solution in the absorber has a much greater ability to absorb the water vapor from the evaporator. The water that remains in the evaporator is chilled by evaporation, which produces a refrigeration or cooling effect within the tank. Both the absorber and evaporator are in a vacuum. This vacuum causes water to boil at a much lower temperature. Because of this, the chilled water can be cooled down to a temperature of 38°F. The evaporator has a pump (shown in figures 17 and 18) which moves the cooled water from the evaporator tank to the spray header. This header sprays the cooled water over the surface of a set of chilled water coils. The evaporation and cooling effect of this spray on the surface of the chilled water coils cool the water inside the coils as it recirculates through the system.

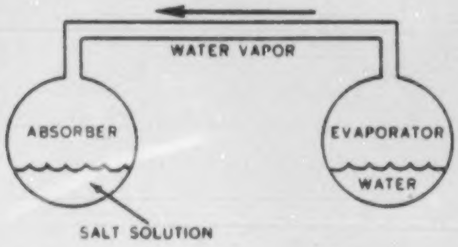
WATER VAPOR
ABSORBER
EVAPORATOR
WATER
SALT SOLUTION

Figure 16.

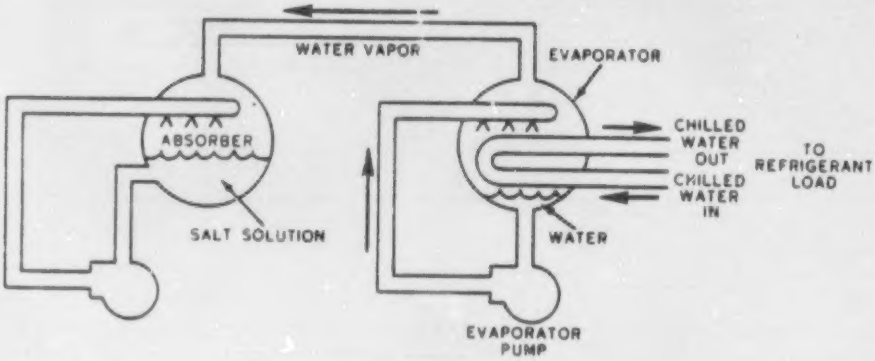
WATER VAPOR
EVAPORATOR
ABSORBER
SALT SOLUTION
CHILLED WATER OUT
CHILLED WATER IN
TO REFRIGERANT LOAD
WATER
EVAPORATOR PUMP

Figure 17.

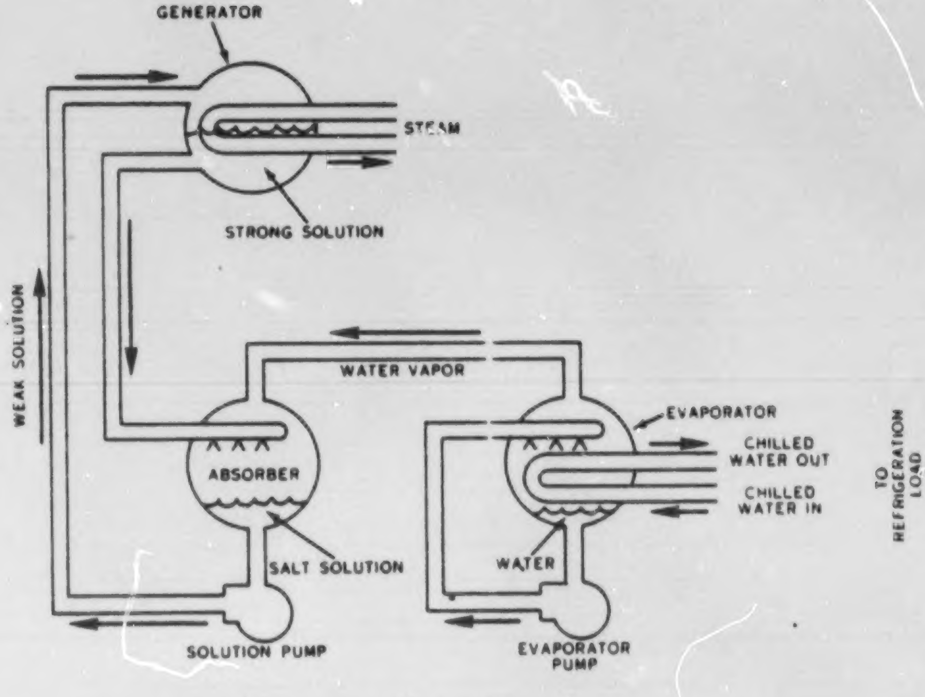
GENERATOR
STEAM
STRONG SOLUTION
WEAK SOLUTION
WATER VAPOR
EVAPORATOR
CHILLED WATER OUT
CHILLED WATER IN
TO REFRIGERATION LOAD
ABSORBER
SALT SOLUTION
WATER
SOLUTION PUMP
EVAPORATOR PUMP

Figure 18

When the water drips from the coils, it will fall into the evaporator tank. Some of the spray will be absorbed by the lithium bromide that is also being sprayed in the absorber. After the salt solution has absorbed as much as it can, the solution becomes weak. It will not absorb any more water vapor. This weak solution is pumped through the heat exchanger to the generator, figure 19, where steam coils cause the water to boil off and leave a strong salt solution. The strong solution will drain from the generator back to the absorber. The water vapor will rise to the condenser. The condensing waterline from the cooling tower will cool the vapors enough for them to liquify. This water flows back to the evaporator tank where it is pumped through the spray header across the coils. The vapor that did not condense in the condenser will flow to the purge unit, and the noncondensable air is discharged into the atmosphere.

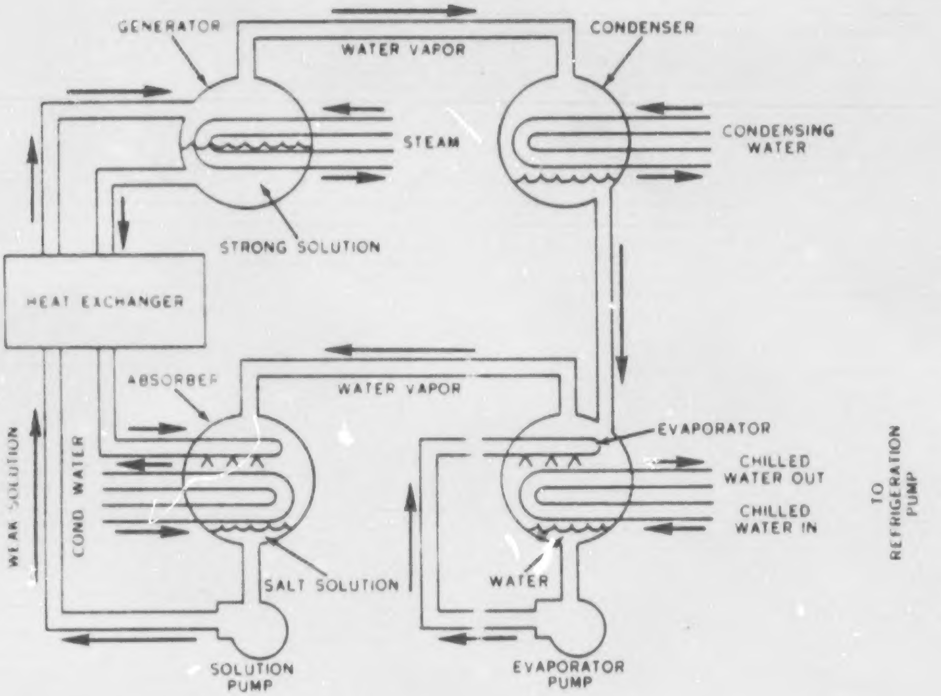
GENERATOR
WATER VAPOR
CONDENSER
STEAM
CONDENSING WATER
STRONG SOLUTION
HEAT EXCHANGER
ABSORBER
WATER VAPOR
EVAPORATOR
CHILLED WATER OUT
CHILLED WATER IN
TO REFRIGERATION PUMP
WEAK SOLUTION
COND WATER
SALT SOLUTION
WATER
SOLUTION PUMP
EVAPORATOR PUMP

Figure 19.

We can compare the basic absorption cycle with the mechanical compression cycle which you have already learned. Refer to figure 20 as you proceed for the comparison.

To simplify the absorption cycle we will start the cycle at the outlet of the condenser and not at the compressor as you are accustomed to.

High pressure liquid refrigerant (water) passes from the condenser (1) through an orifice or restrictor (2) and expands into the lower pressure evaporator (3). As the refrigerant (water) is discharged from the orifice into the evaporator (3) the refrigerant (water) is cooled by flash evaporation. The heat will flow from the water circulating through the conditioned space to the liquid refrigerant, vaporizing the refrigerant.

The refrigerant, now a vapor, flows to the absorber (4) where the pressure is the lowest in the system. In the absorber the vapor is absorbed by the lithium bromide, a salt solution. A combination of absorbent and refrigerant, now mixed, forms a diluted or weak solution. This diluted solution being heavier than the strong absorbent settles to the bottom of the absorber shell where it is pulled out by the solution pump (5). The weak solution is now pumped to the generator or concentrator (6). The refrigerant is recovered from the absorbent in this component by distillation. Heat is applied to the solution by means of low pressure steam or hot water boiling out the refrigerant. The strong absorbent solution returns to the absorber and repeats the process. The refrigerant vapor passes to the condenser (1) where it is cooled and condensed by cooling tower water flowing through a tube bundle.

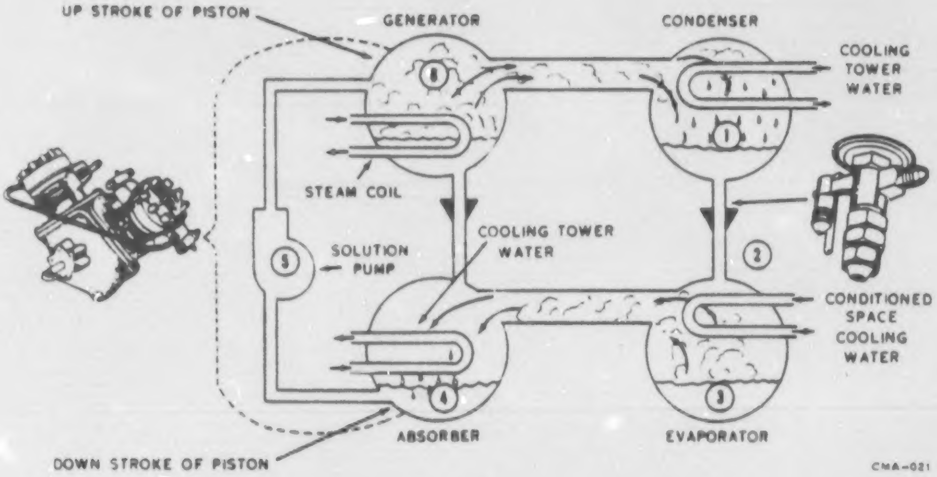
UP STROKE OF PISTON
GENERATOR
CONDENSER
6
COOLING TOWER WATER
1
STEAM COIL
5
SOLUTION PUMP
COOLING TOWER WATER
2
CONDITIONED SPACE COOLING WATER
4
3
ABSORBER
EVAPORATOR
DOWN STROKE OF PISTON
CMA-021

Figure 20. Compression-Absorption Comparison

Absorption System Components - Refer to figure 21, Lithium Bromide System

EVAPORATOR. Chilled water flows through the evaporator tube bundle. It is cooled by the refrigerant being sprayed over the tubes. The chilled water is then pumped to where it furnishes cooling. A refrigerant collection pan, located below the chilled water coils, collects, and stores the refrigerant for further cycling.

ABSORBER. The water vapor formed in the evaporator is absorbed by the lithium bromide solution that is being circulated in the absorber. Cooling water from the tower flows through the tube bundle in the absorber removing the heat of absorption, heat of condensation and sensible heat. The lithium bromide must be kept cool to absorb water.

GENERATOR. Lithium bromide solution is pumped from the absorber to the generator where low-pressure steam, or hot water, provides the heat necessary to boil the solution. Boiling removes the water that was absorbed in the absorber and makes a strong solution out of the weak solution. The strong solution then returns to the absorber section. The low-pressure steam or hot water comes from a boiler.

CONDENSER. The water vapor produced in the generator is condensed in the condenser by the relatively cool condenser water flowing from the absorber. A water pan collects the condensed water vapor and returns it to the evaporator section.

HEAT EXCHANGER. A shell and tube heat exchanger in the lines between the absorber and generator transfers heat from the hot strong solution that is leaving the generator to the weak solution that is entering the generator. This increases the machine's efficiency by causing the solution to be in the generator for a shorter period of time.

PURGE UNIT. The purge unit is a necessary part of the machine. It removes, stores, and discharges to the atmosphere, all air and noncondensables accumulated in the machine. It is composed of three basic sections.

1. Suction Chamber. Weak lithium bromide solution is supplied to this chamber from the discharge of the solution pump. As the solution cools a low pressure area is formed. Noncondensables are then drawn into the chamber from the absorber. Since the absorber is in the lowest vacuum, all air and noncondensables will collect there.

2. Return Chamber. The lithium bromide solution and all noncondensables flow into the return chamber. In this chamber the air and noncondensables bubble up to the storage chamber. The solution is returned to the absorber through a return valve.

3. Storage Chamber. The noncondensables are accumulated in this section until the exhaust cycle when they are discharged to the atmosphere.

PUMPS. The pumps that are used with an absorption air conditioner are usually of the centrifugal type. They are equipped with mechanical seals when they are used in a vacuum, as they are on an absorption air conditioner. These seals require a head of water for lubrication so that water rather than air enters the unit in case the seal leaks. On the later model units the pump and pump motor are hermetically sealed.

Checks and Servicing

SOLUTION LEVEL. The solution level in the absorber must be checked. Normal operating level is approximately one-third of the absorber sight glass at full load operation. At partial-load operation, the solution level will vary between one-third and two-thirds of the sight glass.

ADD OCTYL ALCOHOL. With the machine running, add the recommended amount of octyl alcohol to the solution through the alcohol charging valve in the absorber pump discharge line. The discharge pressure of the absorber solution pump is approximately five to fifteen inches of vacuum; therefore, even with the pump running, it will be possible to draw the alcohol into the machine. This cleans the outside of the tubes in the generator and absorber and improves their efficiency in transferring heat.

REFRIGERANT LEVEL. The refrigerant level is visually checked through the sight glass located on the evaporator. At a high level the water may spill over the evaporator tank into the solution in the absorber, causing a loss of operating efficiency. A low level will cause the evaporator water pump to surge (cavitate) when it is running. A low refrigerant level results in less refrigeration effect.

DRY VACUUM TEST. After completing the annual maintenance, the system should be checked for leaks. Evacuate the system until an absolute pressure of at least .03 inches of mercury is read on the manometer. Record this reading. Check the manometer again 24 hours later. If there is no loss of vacuum then charge the system with solution and refrigerant (water). If the unit does not meet the vacuum requirements, it should be tested for leaks with a leak detector.

To test the system in this manner, it is necessary to first charge the unit with refrigerant R-12 and water pumped nitrogen. Charge the unit with R-12 to five psi or ten inches of mercury, continue charging with nitrogen to about 18 psig. When the charging operations are completed, test the system for leaks with a leak detector. Make permanent repairs to any leaks found.

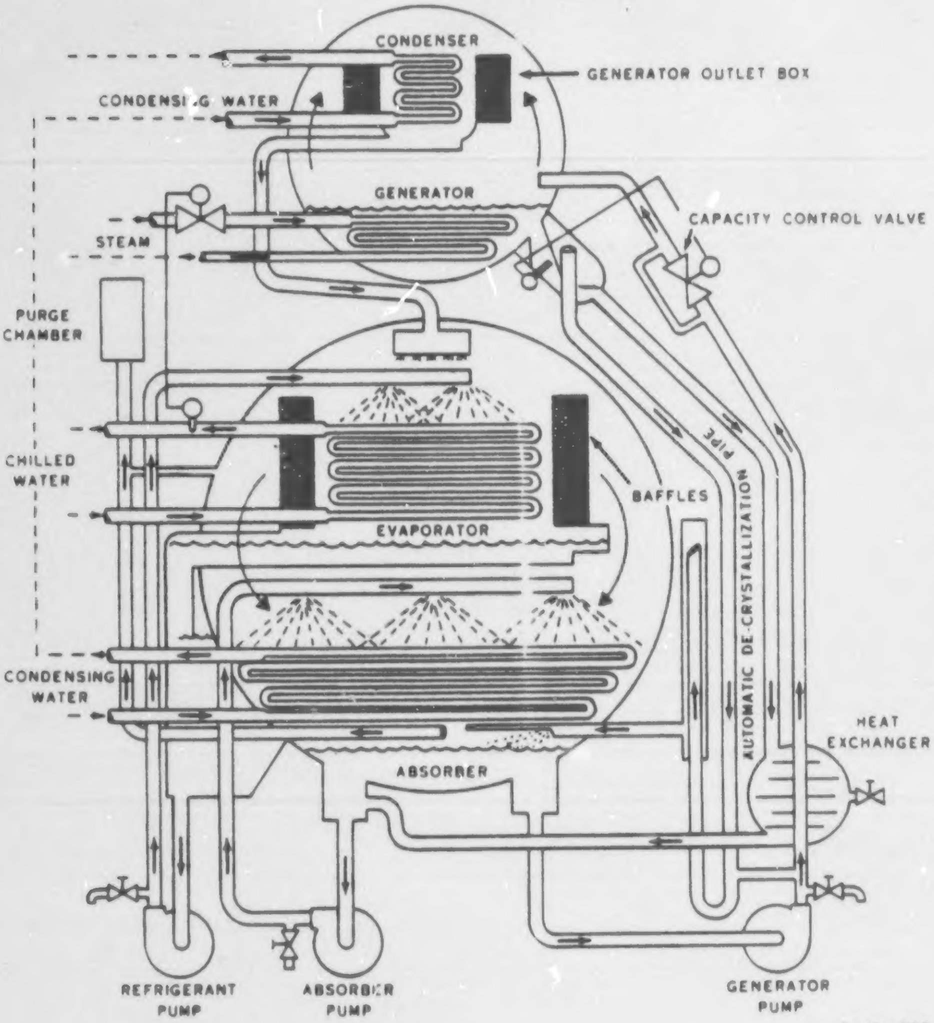
CONDENSER
GENERATOR OUTLET BOX
CONDENSING WATER
GENERATOR
STEAM
CAPACITY CONTROL VALVE
PURGE CHAMBER
CHILLED WATER
BAFFLES
PIPE
EVAPORATOR
AUTOMATIC DE-CRYSTALLIZATION
CONDENSING WATER
HEAT EXCHANGER
ABSORBER
REFRIGERANT PUMP
ABSORBER PUMP
GENERATOR PUMP
C-MA-029

Figure 21. Lithium Bromide System

CHARGING WITH REFRIGERANT AND SOLUTION. After all maintenance is completed and the system passes a satisfactory vacuum test, the unit is ready to be charged with solution and refrigerant. To charge with refrigerant, connect a vacuum pump to the purge connection and let it run for several minutes to lower the absolute pressure of the system (figure 22).

Solution Charging:

1. Connect flexible hose to ½" pipe. Cut end of pipe at a 45° angle to prevent pipe from sealing itself on bottom of drum. Fill both pipe and hose with water.
2. Insert pipe into drum and connect flexible hose to solution pump service valve.
3. Open service valve. Charge the system with the amount specified by the manufacturer for the particular unit. Caution should be exercised to never let the liquid level in the drum drop below the end on the pipe. If this should happen air would be drawn into the unit.

Refrigerant Charging:

1. Same procedure as solution charging.
2. Insert pipe into drum and connect flexible hose to refrigerant pump service valve.
3. Same procedure as solution charging.

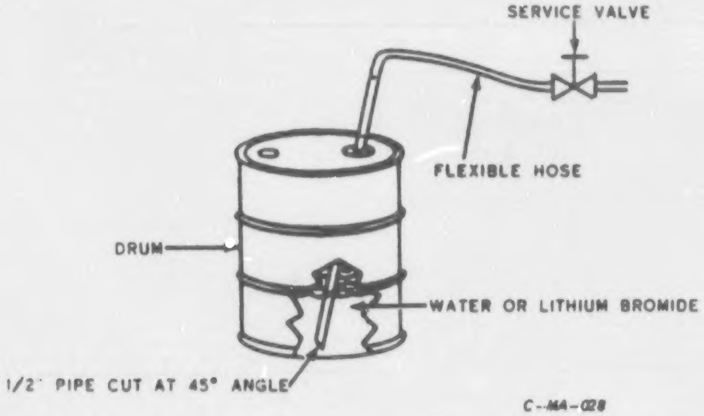

Figure 22. Charging Refrigerant or Solution

LEAK CHECK. Before starting the unit that has the absorbent and refrigerant in it the vacuum should be checked. Air may have entered the system during the charging process or through a leak while it was shut down. To do this, take a manometer reading (figure 23) and the temperature of the machine room. With these two knowns, plot the pressure temperature curve as shown in figure 23A. If the plotted pressure reading is more than .1 inch of mercury higher than the pressure located on the curve there is air in the unit. If this condition recurs on the next two or three startups, the unit should be shut down as soon as possible and tested for leaks. Air (oxygen) in the presence of lithium bromide salt will cause corrosion inside the unit and shorten equipment life.

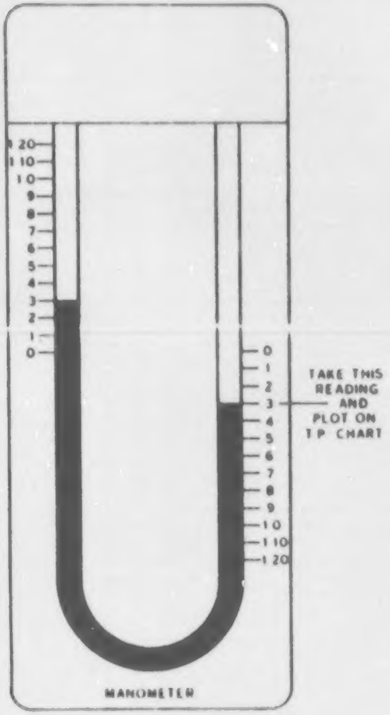
1 20
1 10
1 0
9
8
7
6
5
4
3
2
1
0
0
1
2
3
4
5
6
7
8
9
1 0
1 10
1 20
TAKE THIS READING AND PLOT ON T P CHART
MANOMETER

Figure 23. Manometer

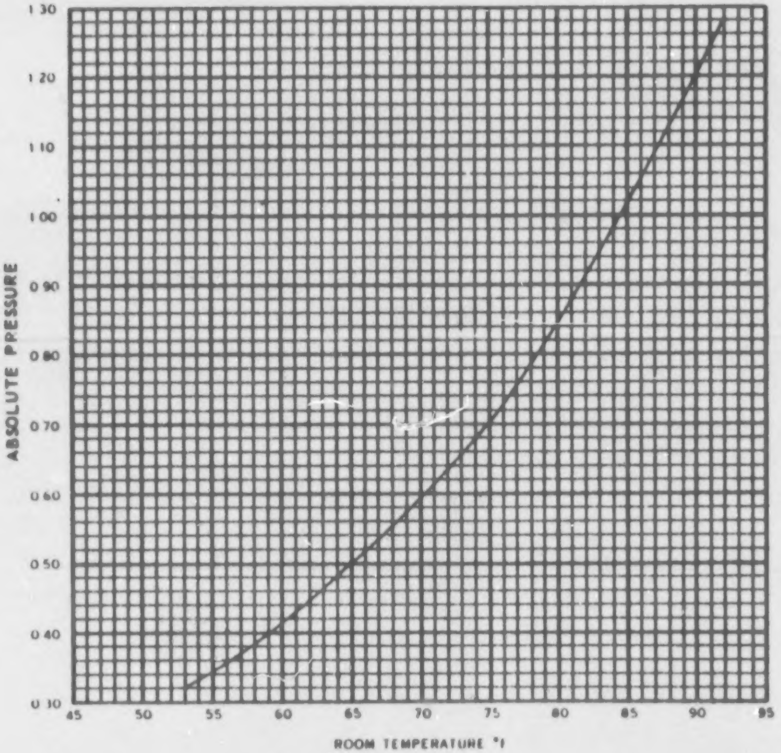

Figure 23A. Temperature-Pressure Chart

SOLUTION CONCENTRATION CHECK. A common characteristic of the lithium bromide absorption air conditioner is that the lithium bromide solution will crystallize or solidify under certain conditions. To solidify or crystallize means the absorbant changes from a liquid to a solid state. Solidification will cause the unit to stop, but will not cause permanent damage to the unit. After the solution is desolidified, the unit may be placed back in operation. To desolidify you would dilute the solidified area with system liquids and, if necessary, apply heat. One method used to determine solution concentration (percent of lithium bromide to water) is as follows. We will use some figures to form an example along with the diagram in figure 25. Use 100° for the temperature of the refrigerant leaving the condenser. Follow the 100° line upward until it gets to the diagonal waterline, mark the chart at this point. Use 160° for the temperature of the solution leaving the generator. Using the mark that you have already made on the chart, go horizonally to the right until you intersect the 160° vertical line. At this point read the solution concentration from the diagonal lines, it would be 65 percent.

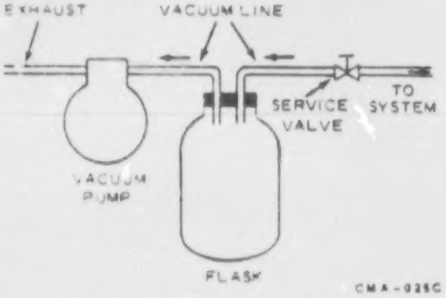

Figure 24. Removing Refrigerant or Solution

REMOVING REFRIGERANT OR SOLUTION. When it is necessary to remove a part or all of the system charge, you may use one of the two methods below. On some units the pump discharge pressure is above atmospheric. On these units just open a valve on the pump discharge and drain out the quantity desired. On units that all pressures are below atmospheric, remove the charge using the following procedure. Refer to figure 24. (1) Connect vacuum hoses to service valve, flask, and vacuum pump. (2) Operate vacuum pump to bring flask pressure below absorption unit pressure. (3) Open service valve and solution or refrigerant will flow into flask.

Absorption System Troubles

In this discussion of absorption machine problems we will limit the coverage to the most common areas. Crystallization (solidification) will take up the major portion of this subject since several common absorption machine problems result in the absorbent solidifing (figure 25).

POWER FAILURE. When a power failure occurs, the machine pumps stop which sets up the condition necessary for crystallization. The power failure prevents the machine from going through a normal dilution cycle. The dilution cycle is a sequence which mixes the weak absorbent solution with the concentrated absorbent solution. This mixture produces a concentration that will not crystallize at room temperature. Without the dilution cycle, the concentrated solution will cool and crystallize at approximately 100°F.

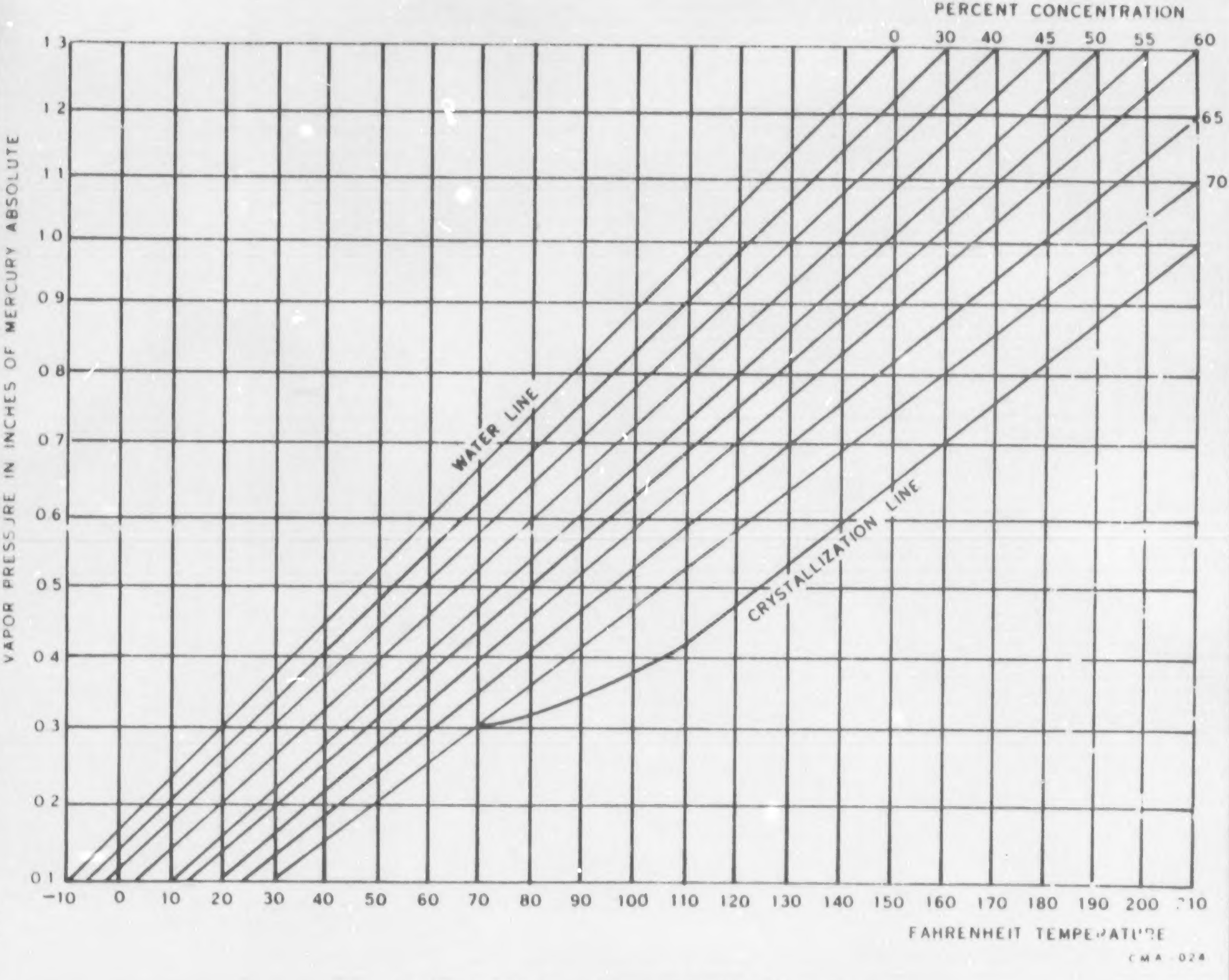

Figure 25. Lithium Bromide Solution Chart

ABSORPTION TROUBLESHOOTING CHART

PROBLEMS	CAUSE	REMEDY
1. Lithium bromide solidifies at startup	a. Condenser water below designed temperature.	a. Reset tower water bypass valve.
	b. Air in machine.	b. Purge system.
	c. Steam pressure too high.	c. Reset pressure regulating valve.
2. Lithium bromide solidifies during operation.	a. Condenser water below design temperature.	a. Reset tower water bypass valve.
	b. Improper purging.	b. Check purge system.
	c. Salt buildup on absorber tubes and spray nozzles.	c. Add octyl alcohol.
3. Low capacity.	a. Air in machine.	a. Repair leak and/or purge system.
	b. Scale in condenser tubes.	b. Remove scale and treat water.
	c. Not enough solution concentration in generator.	c. Check amount of steam flow and pressure.
	d. Refrigerant overflow from evaporator to absorber.	d. Remove part of refrigerant charge.
	e. Capacity control valve returning too much weak solution back to absorber.	e. Reset control to correct temperature.
4. Machine shuts down on safety controls.	a. Motor overload opens.	a. Find reason and reset overload.
	b. Low refrigerant temperature.	b. Check temperature controller. Reset if needed.
5. Solidification during shutdown.	a. Dilution cycle not long enough.	a. Lengthen dilution cycle to at least 7 minutes.
	b. No load when diluting.	b. Open reclaiming valve to put load on machine.
6. Air leak into machine.	a. Any connection, fitting, or component exposed to atmosphere may be cause.	a. (1) Perform leak check. (2) Check vertical purge.
7. Loss of vacuum at shutdown.	a. Air leakage into machine.	a. (1) Check for leakage at valves. (2) Perform leak check.
8. Failure to keep machine purged.	a. Air leakage into machine.	a. Perform leak check.
	b. Vertical purge not removing noncondensables properly.	b. (1) Check rate of purge. (2) Purge solution solidified. Desolidify.

Figure 26. Troubleshooting Chart

CONDENSER WATER. Condenser water is the water coming from the cooling tower. It enters the system at the absorber. A drop in this water temperature below its normal 85°F can cause the strong solution to solidify in the heat exchanger. Should the water temperature drop from 85°F to 55°F, the temperature of the diluted solution going through the heat exchanger would be too cool. This would reduce the temperature of the strong solution leaving the heat exchanger to approximately 100°F, thus causing the solution to begin solidifying. Accurate control is very important for condenser water. A malfunction in this system will cause not only crystallization but also loss of system efficiency.

LOSS OF VACUUM. This problem may occur as the results of an air leak, loss of purge, bad pump seal, etc. When air leaks into the system the absorber pressure rises with the presence of noncondensables, thus limiting evaporator capacity. The leaving chilled water temperature will then rise, which signals the steam valve to open. This causes the generator temperature to increase and produces a more concentrated solution. With the increasing pressure there is less load on the absorber which results in a decrease in the diluted solution temperature. This cooler diluted solution, passing through the heat exchanger cools the concentrated solution sufficiently to cause crystallization. Air leakage, without a doubt, is the worst enemy of absorption equipment. The consequences are serious because in the presence of air, lithium bromide becomes corrosive to metal and is subject to solidification. As you study the troubleshooting chart, figure 26, you will see other problems with the absorption machine. We have listed some possible causes and remedies for these problems.

ABSORPTION UNIT CONTROLS. The operation of an absorption air conditioner can be compared to an expensive airplane. When either one is out of control, they do not perform the way they should. It is, therefore, important that you understand the control circuits of the lithium bromide system.

Absorption systems use electric, electronic, and pneumatic controls. We will explain the operation of a typical control circuit as you refer to figure 27.

OPERATION. When the main switch is turned on it supplies voltage to the control voltage line. The start-stop switch (S/S) is energized to the start position, starting the chilled water pump thru LS-2 which is interlocked with a set of auxiliary motor starter contacts. In series with the auxiliary contacts is a flow switch (FS). Once flow has been established in the chilled water circuit, the flow switch (FS) closes supplying voltage to the pneumatic electric switch (PE).

Upon a rise in temperature in the chilled water supply line the branch line pressure of the chilled water thermostat (T-1) will rise. The rise in branch line pressure causes the contacts in the pneumatic electric switch (PE) to close, which energizes the condensing water line starter (LS-3) starting the condenser pump. The cooling tower line starter (LS-4) is energized simultaneously through auxiliary contacts starting the cooling tower fan. Once the cooling tower fan is in operation the cooling tower thermostat (T-2) will cycle the fan on and off to maintain designed cooling water temperature.

Turning the system's on-off switch (S-1) on, energizing the time delay relay (TD). This supplies control voltage to the unit pump's line starter (LS-1) thru the normally closed low temperature control (LTC), motor temperature control (MTC), and the liquid level switch (LL) starting the pumps.

Energizing the unit pump line starter (LS-1) closes auxiliary contacts to supply control voltage to the solenoid air valve (SV-1). This opens the solenoid supplying branch pressure to the steam valve.

Systems water temperature changes are sensed by the chilled water thermostat (T-1). The thermostat responds by varying the branch line pressure to the steam valve.

When lower chilled water temperature is sensed by T-1, indicating that cooling is no longer needed, the branch line pressure will decrease causing the pneumatic electric switch (PE) to open. This deenergizes the condenser pump line starter (LS-3) which in turn deenergizes the time delay relay (TD), solenoid air valve (SV-1), and the cooling tower fan line starter (LS-4) stopping the fan. The loss of control voltage to the solenoid air valve (SV-1) causes the steam valve to close, stopping steam to the generator.

Prior to complete shutdown, the unit pumps will continue to operate for approximately seven minutes, under control of the time delay relay (TD), allowing the mixture of weak and strong solution. This equalization of the solution throughout the solution handling portion of the system eliminates the possibility of crystallization during shutdown.

The purge pump and purge pump solenoid valve (SV-2) are energized by closing the purge pump on and off switch (S-2).

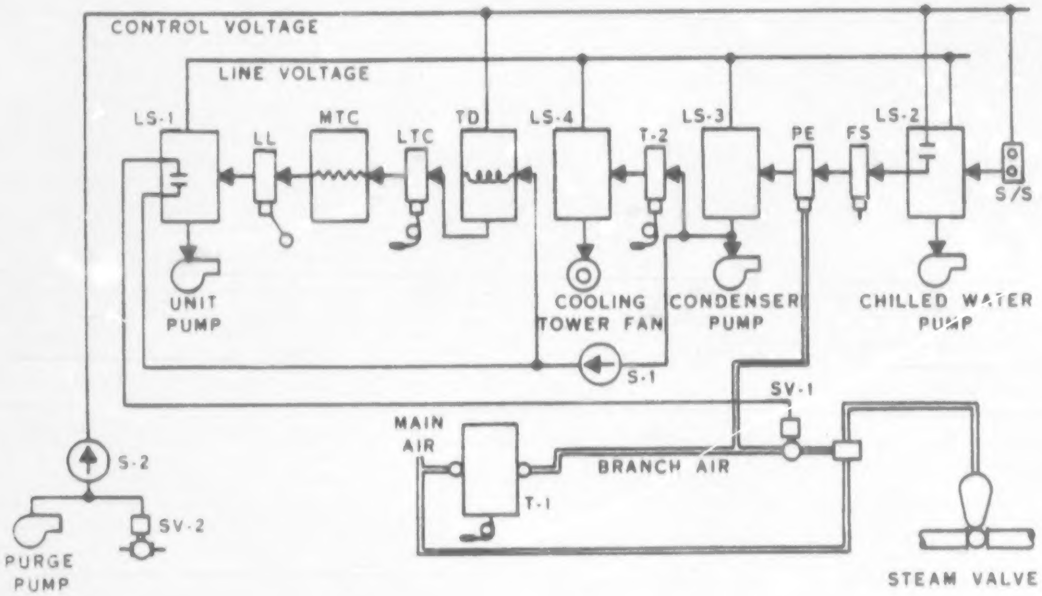
CONTROL VOLTAGE
LINE VOLTAGE
LS-1
LL
MTC
LTC
TD
LS-4
T-2
LS-3
PE
FS
LS-2
S/S
UNIT PUMP
COOLING TOWER FAN
CONDENSER PUMP
CHILLED WATER PUMP
S-1
SV-1
MAIN AIR
BRANCH AIR
T-1
S-2
SV-2
PURGE PUMP
STEAM VALVE

Figure 27. Lithium Bromide Electrical System

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Care and Handling of Lithium Bromide

Lithium bromide is nontoxic, nonflammable, and nonexplosive. It can easily be handled in an open container. This solution is chemically stable and does not undergo any noticeable change in properties even after years of use in the absorption machine.

Lithium bromide solution is corrosive when exposed to air. If any solution is spilled on exposed parts or tools, it should be wiped off and rinsed with fresh water as soon as possible. Tools should be coated with a light film of oil after rinsing with fresh water to prevent rust.

Empty metal containers used for solution should also be rinsed with fresh water to prevent corrosion. Lithium bromide solution may be irritating to the skin and to the eyes. It should be washed off with soap and water. If it gets into the eyes, wash with fresh water and consult a physician immediately. Lithium bromide is a strong salt solution; do not siphon by mouth.

SUMMARY

The absorption system operates on the principle of one material being able to absorb or take up the vapors of another substance and thus reduce the pressure.

The absorption refrigeration unit consists of a generator assembly and an absorber assembly. The condenser and generator are combined in the generator assembly, or upper shell of the unit; while the evaporator and absorber are combined in the absorber assembly, or lower shell of the unit. The control panel is located on the side of the absorber assembly. The other minor units, such as the absorber sight glass, solution heat exchanger, and the solution pump are usually mounted between the supporting legs of the absorption unit.

Air leakage into the machine is the cause of many troubles. It will cause decreased refrigeration effect and crystallization of the lithium bromide solution. Some other troubles that you will encounter is with controls, improper setting of valves and system temperatures not within operating range.

This system is used for air conditioning and industrial process cooling. The evaporator design temperature is normally 38°F. These units are made in a wide range of sizes, varying from 3 to over 5000 tons.

QUESTIONS

1. What is used as the refrigerant in the aqua-lithium bromide system?

2. How can you locate a leak in an aqua-lithium bromide system?

3. What is the purpose of routing the condensing water through the absorber?

4. What is the purpose of the purge unit?

5. What are two causes of solution solidification?

6. Why is the water pumped through the spray header?

7. What is the minimum evaporator temperature in the aqua-lithium bromide system?

8. What safety precautions should be observed when handling lithium bromide?

9. What is octyl alcohol used for?

10. Solution and chilled water pumps are equipped with what type of seals?

11. What is the primary application of the lithium bromide absorption system?

REFERENCES

1. Service Manual, 16HA Hermetic Absorption Machine, Carrier
2. Textbook, Refrigeration and Air-Conditioning Service Application Manual (RSES)
3. Service Manual, York Absorption System

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WORKBOOKS 3ABR54530-VI-5-P1 thru VI-6-P7

Department of Civil Engineering Training

Refrigeration and Air-Conditioning Specialist

WATER CONDITIONING AND ABSORPTION AIR-CONDITIONING SYSTEM

January 1975

SHEPPARD AIR FORCE BASE

11-8

Designed For ATC Course Use

DO NOT USE ON THE JOB

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Refrigeration and Air-Conditioning Specialist

(Days 51-55)

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This supersedes SG 3ABR54530-VI-5 and 6 and W Bs 3ABR54530-VI-4-P1 thru VI-5-P7, 28 October 1973.
Copies of superseded publication may be used until supply is exhausted.

Department of Civil Engineering Tng
Sheppard AFB, Texas

WB 3ABR54530-VI-5-P1
22 January 1975

CHEMICALLY TREAT WATER FOR CORROSION

OBJECTIVE

You are required to chemically treat water for corrosion by adding the necessary chemicals.

Testing With Litmus Paper

1. Secure a 250 milliliter (ML) beaker.

2. Pour approximately 20 ML of sample solution marked "pH-1" into the beaker.

3. Drop a strip of blue litmus paper into the sample solution.

   a. What color does the litmus paper turn? ______________________

   b. Is solution "pH-1" acid or basic? ______________________

4. Clean your beaker and place approximately 20 ML of sample solution marked "pH-2" into the beaker.

5. Drop a strip of red litmus paper into sample "pH-2" solution.

   a. What color does the litmus paper turn? ______________________

   b. Is solution "pH-2" acid or basic? ______________________

   NOTE: Keep your "pH-2" sample for the "P" test.

Testing With "P" Indicator

1. Place about five drops of "P" indicator into the sample of "pH-2" solution.

   a. What is the color of the solution? ______________________

   b. Does this indicate acid or basic? ______________________

Testing For pH Using a Color Comparator

1. Obtain a pH tester and place it on a clean working table.

2. Secure a sample solution marked "pH-3".

3. Check sample "pH-3" with litmus paper.

   Is the sample acid or basic? ______________________

4. Select a pH disc and place it in the comparator.

   What disc did you select? ______________________________

5. Fill both test tubes to the 15 ML mark with test sample and place them in the comparator.

6. To the left-hand tube, add 0.5 ML of the proper pH indicator solution and mix it well.

7. Lift the comparator from the table and turn the lens toward natural light (not directly into the sun).

8. Turn the disc until two colors match.

9. Read the pH from the numbered disc.

   What is the pH of sample "pH-3" ______________________________

Adjusting pH

1. Add either dilute sodium hydroxide (NaOH) or dilute sulphuric acid (H_2SO_4) to the sample to produce a pH of 8.0.

2. Clean all equipment and return it to its proper place.

3. What causes corrosion? ______________________________

   ____

4. What chemicals are used to prevent corrosion? ______________________________

   ____

5. What acid is used to chemically clean a system that has mild corrosion in it?

   ____

6. To raise the pH of water what is used? ______________________________

7. To lower the pH of water what is used? ______________________________

   ____

8. What are surface active agents? ______________________________

   ____

9. How does a surface active agent work? ______________________________

____

____

10. What must be done if severe corrosion is present in an air-conditioning system?

____

Checked by ______________________
Instructor

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CHEMICALLY TREAT WATER FOR SCALE

OBJECTIVE

Each of you are required to chemically treat water for scale by adding the necessary chemicals.

Phosphate Test

1. Preparation of dilute stannous chloride:

   a. Add 0.5 ML of stannous chloride to "Dilute Stannous Chloride" bottle.
   b. Add distilled water to shoulder of bottle.
   c. Mix.

2. Test Procedure

   a. Secure a phosphate color comparator block, one bottle Comparator Molybdate Reagent, one dropper bottle stannous chloride reagent, and a sample of cooling tower water.

   b. Add sample water to the 5 ML mark in the mixing tube.

   c. Add comparator Molybdate Reagent to bring the level up the 15 ML mark.

   d. Place stopper in tip of mixing tube and mix by inverting the tube several times.

   e. Add fresh Dilute Stannous Chloride up to the 17.5 ML mark.

   f. Place stopper in top of mixing tube and mix by inverting several times.

   g. Place mixing tube into comparator block, and compare colors.

   h. Your sample has ________________ ppm of phosphates.

   i. If your sample is below the required amount add more phosphates to your sample and retest water sample.

   j. If your sample is above the required amount, add more water to your sample and retest water sample.

   k. What causes scale to form? ____

   ____

   l. What is scale? ____

   ____

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m. What can be done to prevent scale? ____________________

____

____

n. What tests are performed to find out if water will cause scale? ____________________

____

o. What effect will scale have on an air-conditioning system? ____________________

____

____

p. Where will scale form in an air-conditioning system? ____________________

____

q. What is used to remove scale? ____________________

____

r. Clean all equipment and return it to its proper place.

Checked By ____________________
Instructor

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CHEMICALLY TREAT WATER FOR ALGAE

OBJECTIVE

To be able to identify algae and procedures for controlling algae in cooling towers.

Identification of Algae

1. Refer to Study Guide 3ABR54530-VI-5 and answer the following questions.

   a. What is algae? ______________________________

   ____

   b. What pH range promotes the growth of algae?

   From ______________ to ______________

   c. What is the effect of algae on a cooling tower system?

   (1) ______________________________

   (2) ______________________________

   (3) ______________________________

   d. __________ ppm to __________ ppm of chlorine should be maintained in the cooling tower for control of algae.

Testing and Adjusting Chlorine Content for Algae Control

1. Secure a sample of water to be tested.

2. Fill both tubes of the standard comparator to the 15 ML mark with test sample, and place them in the comparator tester.

3. Using the graduated dropper, add .75 ML of ortho-tolidine solution to the left-hand tube.

4. Revolve the chlorine color disc until there is a match in color.

5. Read the results directly.

   ______________________ ppm Chloride

6. Adjust the chlorine content of the sample to 1.5 ppm using tap water or calcium hypochlorite solution.

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7. Clean all equipment and return it to its proper place.

Checked by ______________________________
Instructor

IDENTIFY COMPONENTS OF A WATER CONDITIONING SYSTEM

OBJECTIVE

To identify the components of a pot type water conditioner.

PERFORMANCE

From the diagram in figure 1, write the name of the component beside the matching number in the diagram, and indicate direction of water flow using arrows.

1. ______________________
2. ______________________
3. ______________________
4. ______________________
5. ______________________
6. ______________________
7. ______________________
8. ______________________
9. ______________________

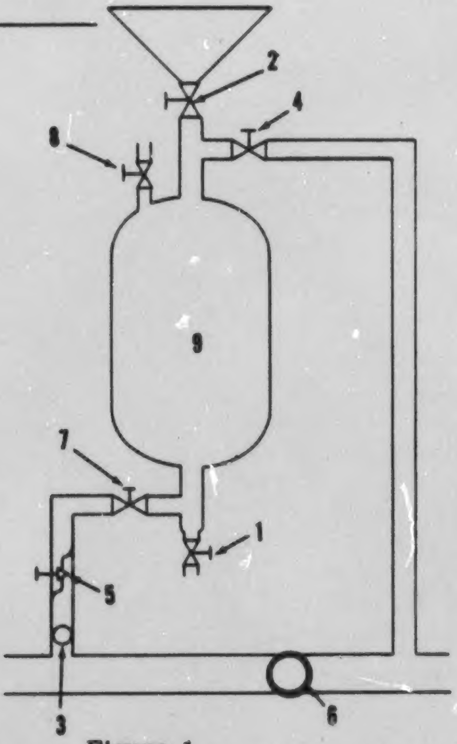

Figure 1

Checked by ______________________
Instructor

IDENTIFICATION OF MAJOR COMPONENTS OF A LITHIUM BROMIDE ABSORPTION SYSTEM

OBJECTIVE

To identify the major components of a Lithium Bromide Absorption System.

1. Identify the lettered components in figure 2 and write their names after the corresponding letters below.

a. ____________________

b. ____________________

c. ____________________

d. ____________________

e. ____________________

f. ____________________

g. ____________________

h. ____________________

i. ____________________

j. ____________________

k. ____________________

l. ____________________

m. ____________________

Checked by ____________________
Instructor

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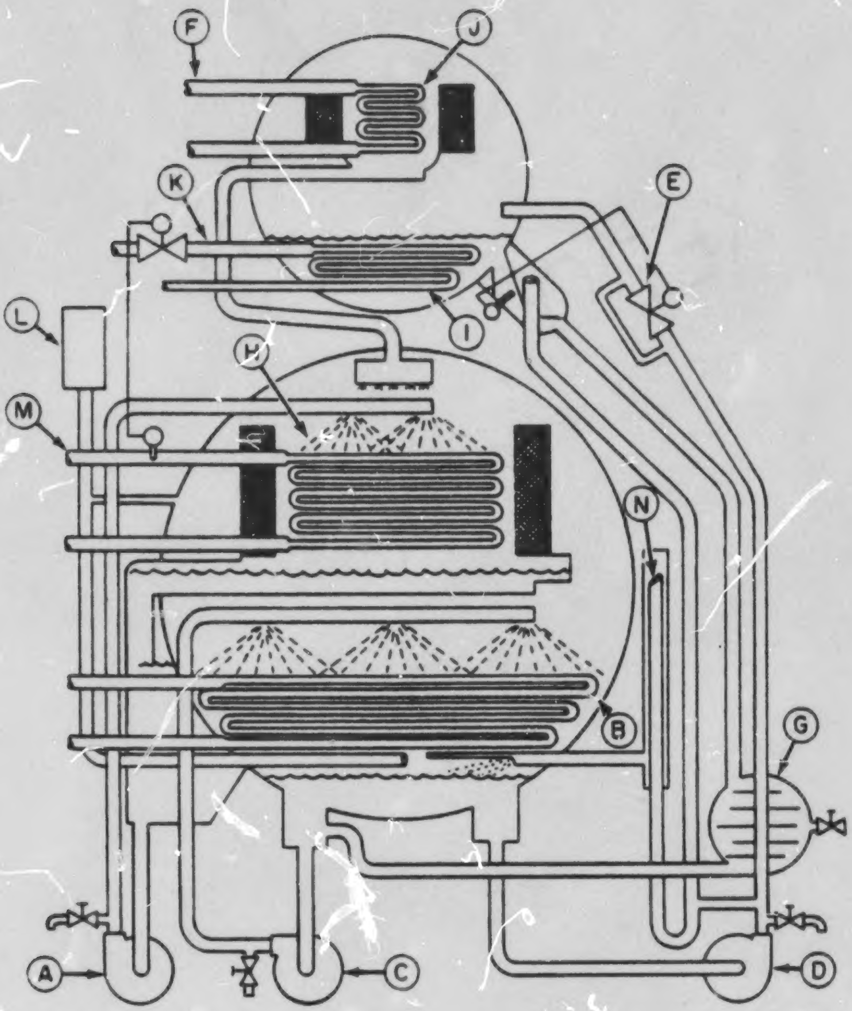
F
J
K
E
L
I
H
M
N
B
G
A
C
D

Figure 2 . Lithium Bromide Absorption System

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REFRIGERANT AND ABSORBANT FLOW

OBJECTIVE

To locate and trace the flow of refrigerant and absorbent in a Lithium Bromide System.

1. Obtain a red and blue pencil from your instructor.
2. Refer to figure 3 .
3. Color in the flow of weak solution from the bottom of the absorber to the generator using light red. Draw an arrow to show direction of flow.
4. Color in the flow of strong solution from generator to absorber spray nozzles using heavy, dark red coloring. Draw an arrow to show direction of flow.
5. Color in primary refrigerant flow from condenser to evaporator using heavy dark blue coloring. Draw an arrow to show direction of flow.
6. Color in cooling tower water using light blue coloring. Draw arrow showing direction of flow.
7. Color in chill-water flow using a regular pencil. Label the chill-water line "Chill Water".
8. Locate the steam line and label it "Steam Line".

Checked by ______________________
Instructor

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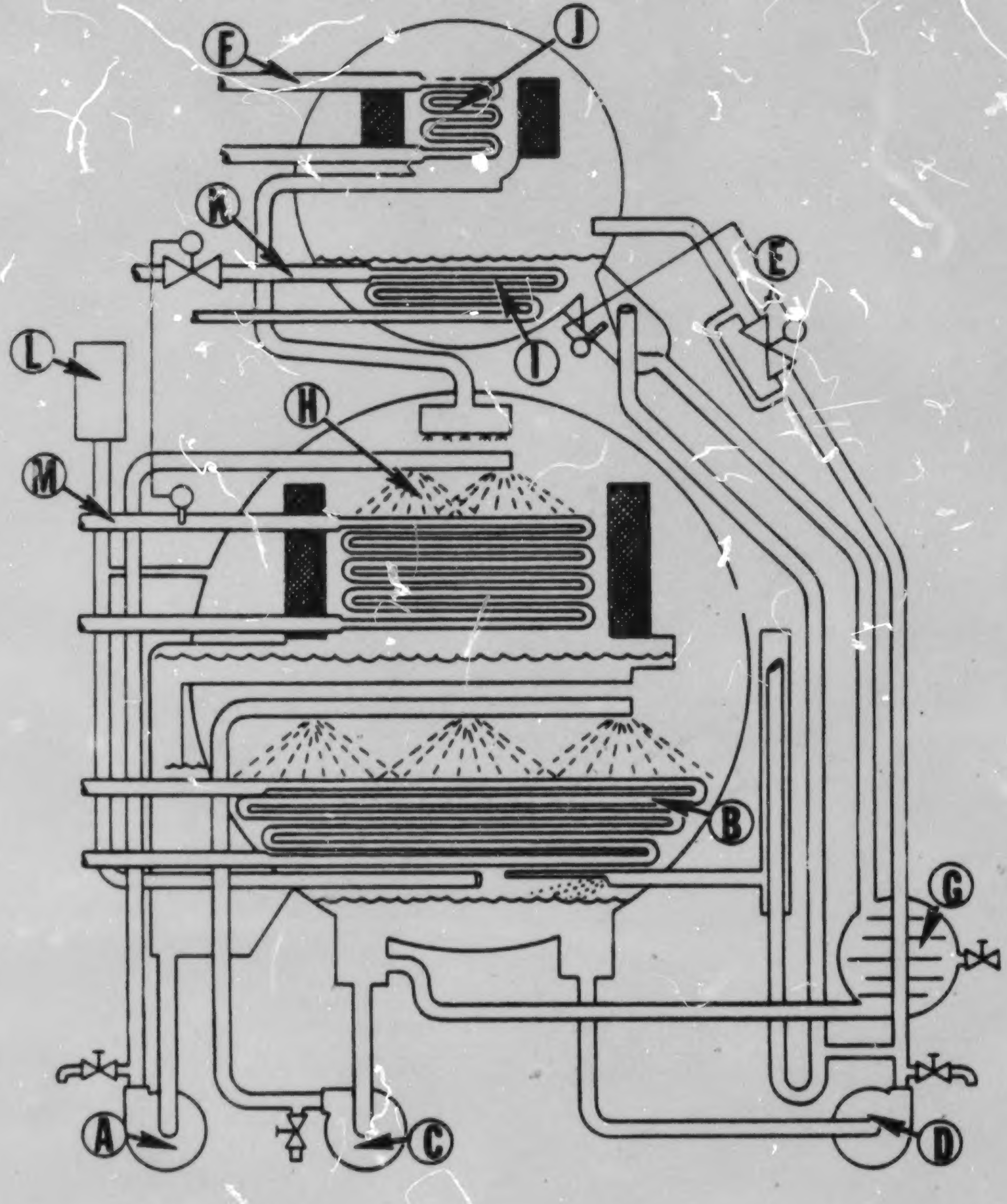

F
J
K
E
I
L
H
M
B
G
A
C
D

CMA-029A

Figure 3 . Lithium Bromide Absorption System

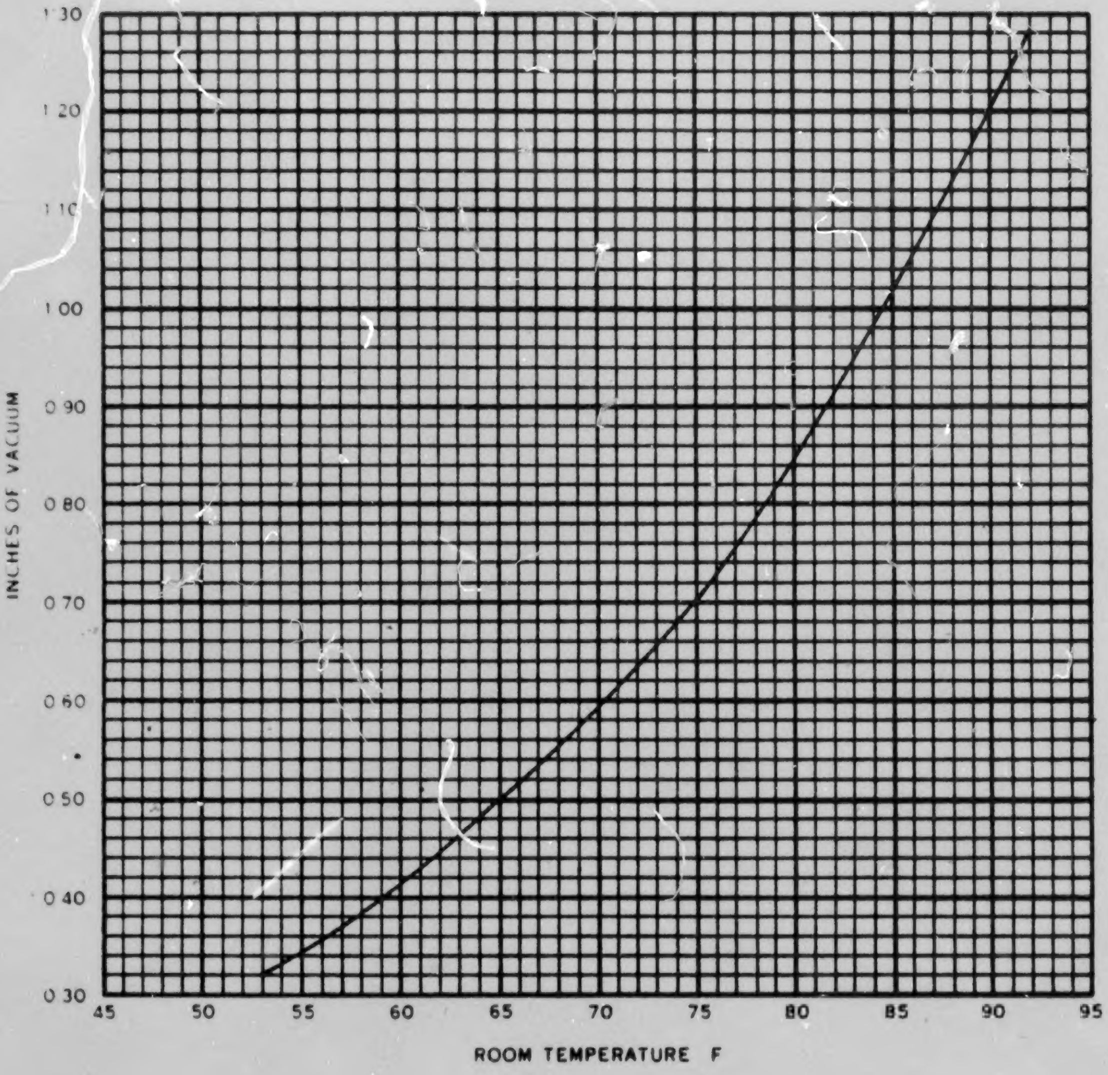
CHECKING MACHINE VACUUM

OBJECTIVE

To plot a pressure-temperature curve and determine the quality of the vacuum inside an absorption system.

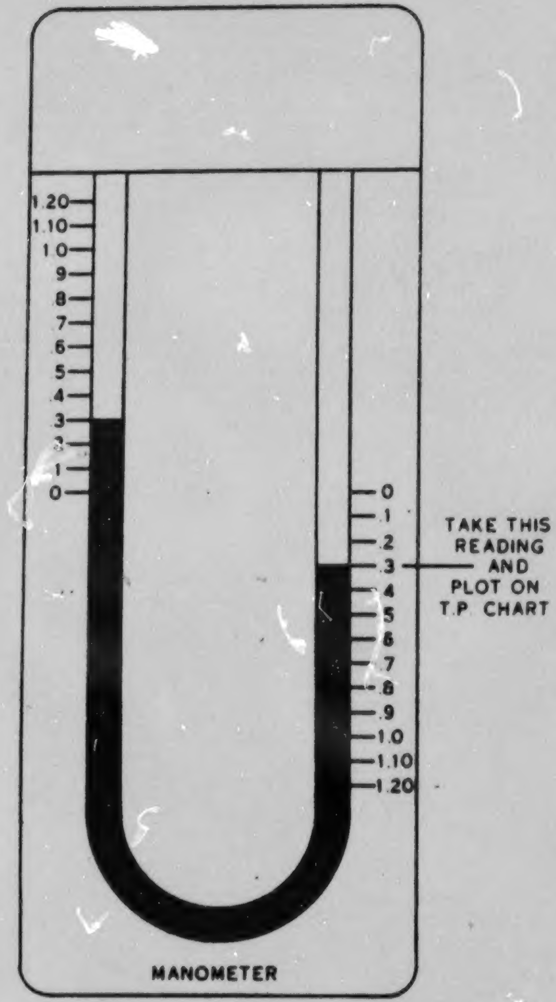
1. Refer to figure 4 and 5 and complete the material below.
2. Figure 4 is a picture of a ________________________________.
3. Figure 5 is a picture of a ________________ ________________ chart.
4. To determine the quality of the vacuum, two things must be known; the ambient ________________ and the present ________________ reading.
5. The maximum allowable pressure above the curve is ________ of one inch of vacuum.
6. The curve on the P-T chart represents the corresponding increase in pressure for each increase in ________________________________.
7. The curve also represents the decrease in pressure that would follow each decrease in ________________________________.
8. With an equipment room temperature of 75° and a manometer reading of 0.70, the vacuum would be (within limits) (outside limits).
9. With a room temperature of 75° and a reading of 0.90, the vacuum would be (within limits) (outside limits).
10. An equipment room temperature of 65° and a press reading of 1.10 inches normally indicates that the system has ________ inside it.

Checked by ________________________
Instructor



INCHES OF VACUUM
1.30
1.20
1.10
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
45
50
55
60
65
70
75
80
85
90
95
ROOM TEMPERATURE F

Figure 4


1.20
1.10
1.0
9
8
7
6
5
.4
.3
.2
1
0
0
.1
.2
.3
.4
.5
.6
.7
.8
.9
1.0
1.10
1.20
MANOMETER

TAKE THIS READING AND PLOT ON T.P. CHART

Figure 5

ADDING AND REMOVING OF REFRIGERANT AND ABSORBANT

OBJECTIVE

Each of you are required to learn how to add and remove refrigerant and solution to and from a lithium bromide absorption system.

Adding Refrigerant or Solution

1. Refer to figures 6 and 7.

2. When adding refrigerant the flexible hose is connected to ____________________ service valve.

3. When adding absorbent the flexible hose is connected to ____________________

   or ____________________ service valve.

4. How is the refrigerant or absorbent forced into the machine? ________________

   ____

5. Why is the pipe cut at one end at a 45° angle? ____________________

   ____

6. Why is the flexible hose filled with water before connecting it to the service valve?

   ____

Removing Refrigerant or Solution

1. Refer to figures 7 and 8.

2. What are the two methods of removing refrigerant or solution?

   a. ____________________

   b. ____________________

3. What is the heavy glass flask used for? ____________________

   ____

4. When removing refrigerant from the system the vacuum line is connected to what

   service valve? ____________________________________

5. When removing solution from the system the vacuum line is connected to what service valve? ______________________ or ________________________________.

6. When an auxiliary vacuum pump is not available, what is used as a vacuum pump to remove refrigerant or solution? ____

7. When removing refrigerant or solution from the system, how long should the vacuum pump be run? ____

Checked By ______________________
Instructor

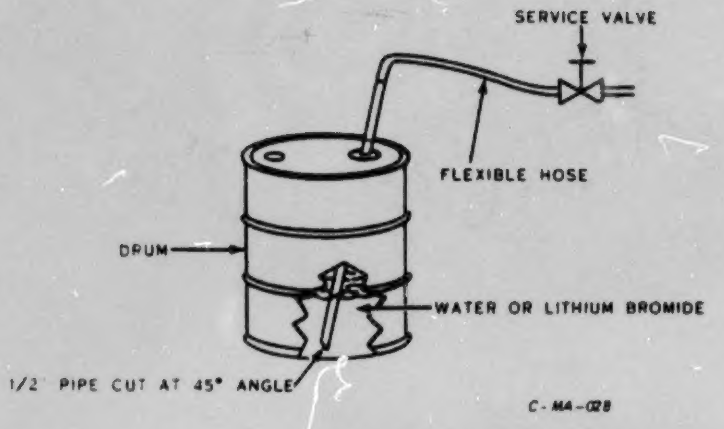

SERVICE VALVE
FLEXIBLE HOSE
DRUM
WATER OR LITHIUM BROMIDE
1/2" PIPE CUT AT 45° ANGLE
C-MA-028

Figure 6. Charging Refrigerant or Solution

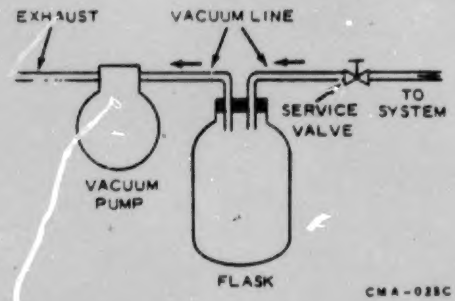
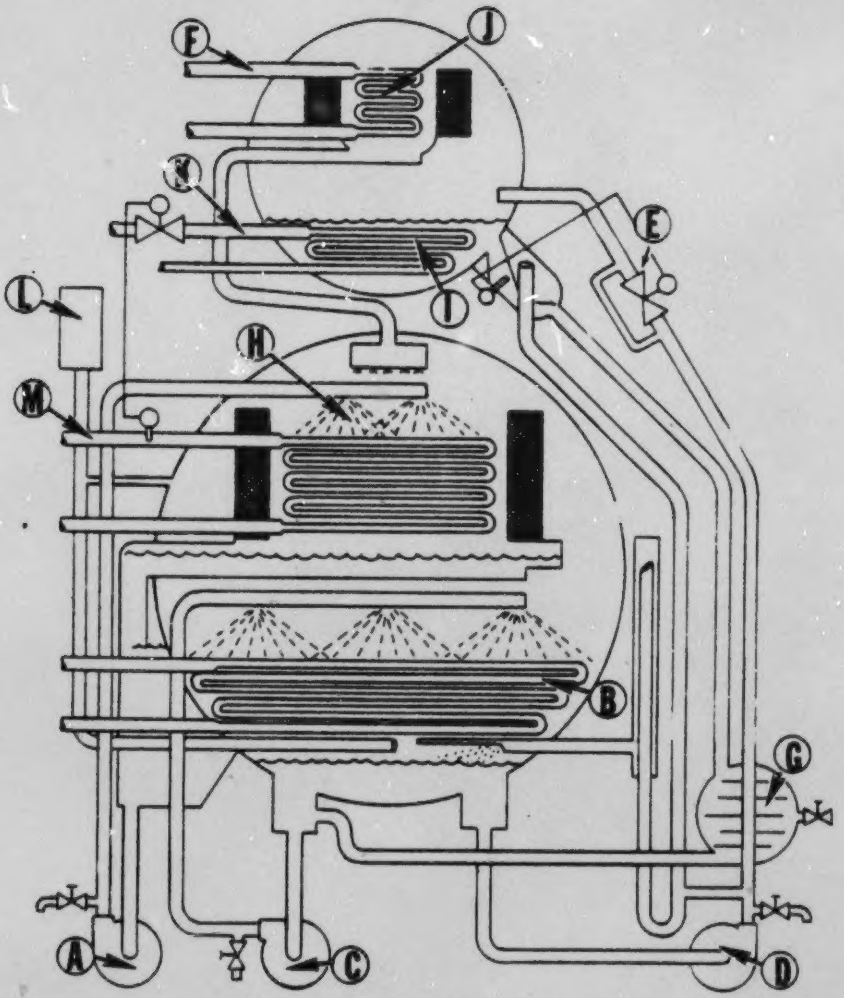

EXHAUST
VACUUM LINE
TO SYSTEM
SERVICE VALVE
VACUUM PUMP
FLASK
CMA-028C

Figure 7. Removing Refrigerant or Solution


F
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A
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D

CMA-029A

Figure 8. Lithium Bromide Absorption System

STUDENT NOTES:

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ABSORBANT CONCENTRATION

PART I

OBJECTIVE

This project will give you practical experience in determining the concentration of the strong lithium bromide solution.

1. Use the solution chart in figure 9.
2. Another word meaning crystallization is ________________________.
3. To use this chart, we must know the temperature of the refrigerant coming out of the ____________________________.
4. With a leaving refrigerant temperature of 110° and a leaving solution temperature of 170°, the solution concentration would be _______________ percent.
5. With a leaving refrigerant temperature of 70° and a leaving solution temperature of 175° we can expect the lithium bromide solution to be ______________________.
6. If the leaving solution temperature was 160° and the condenser water was too cold causing the temperature of the refrigerant leaving the condenser to be 75°, the solution would be ____.

Checked by __________________________
Instructor

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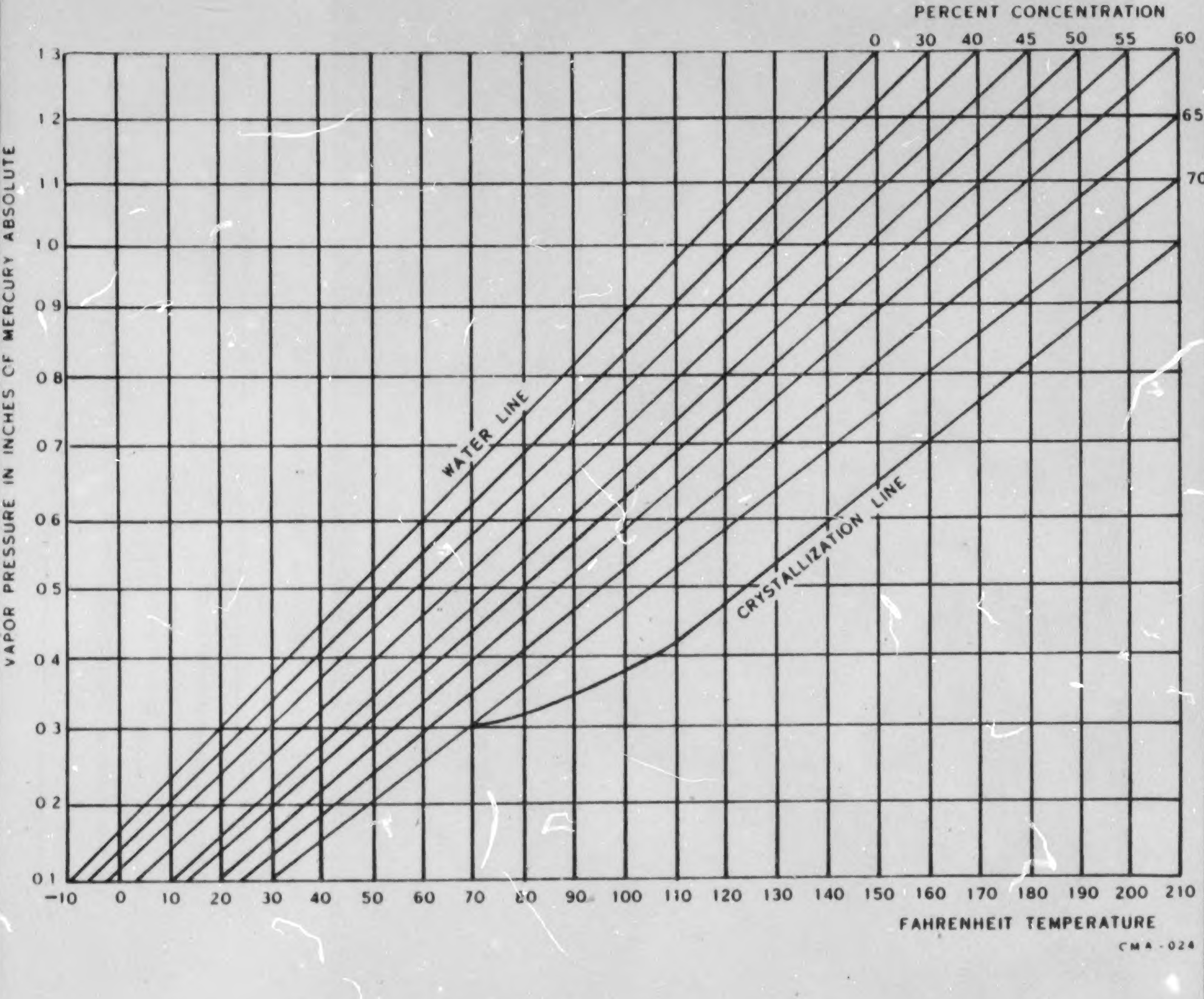
PERCENT CONCENTRATION
0
30
40
45
50
55
60
65
70
WATER LINE
CRYSTALLIZATION LINE
VAPOR PRESSURE IN INCHES OF MERCURY ABSOLUTE
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
−10
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
210
FAHRENHEIT TEMPERATURE
CMA-024

Figure 9

EQUILIBRIUM DIAGRAM

PART II

OBJECTIVE

This project will give you practical experience in plotting the behavior of the Lithium Bromide solution.

1. Use the equilibrium diagram in figure 10.
2. The pressures in this diagram are ______________ pressures.
3. Plotted on this chart is the normal behavior pattern for Lithium Bromide solution. The concentration varies from ____________ to __________ %.
4. The specific gravity of the solution is determined by using a ________________.
5. With a specific gravity of 1.71 and a solution temperature of 170°F the concentration of the Lithium Bromide solution would be ___________ %.
6. In line 1 to 2 on the diagram, the absorber is absorbing water vapor. Two things are happening here--the concentration ______________ and the solution temperature ______________.
7. When the solution plot falls in the lower right-hand corner of the diagram below the crystallization line, the solution will __________________.
8. If there were too much steam heat, point 5 on the diagram would move in which direction? ____.
9. Too much steam would cause an ______________ in temperature and an ______________ in concentration.
10. Point 5 to 6 on the diagram represents strong solution entering and leaving the ______________ ______________ on the way to the absorber.

Checked by ________________________
Instructor

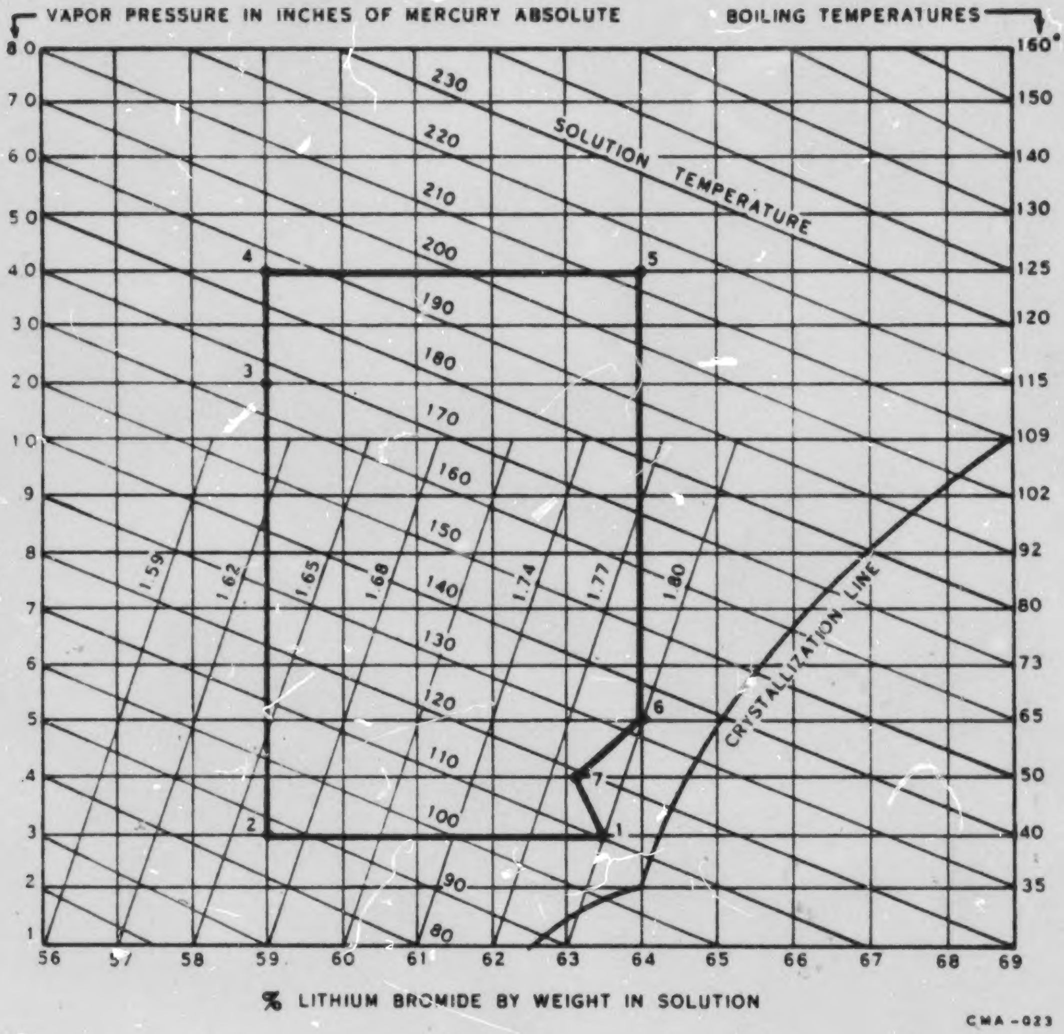

Figure 10. Equilibrium Diagram

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LITHIUM BROMIDE AIR-CONDITIONING WIRING DIAGRAM

OBJECTIVE

To learn how to read wiring diagrams for use in checking system operation and troubleshooting.

1. Refer to figure 11.

2. Identify the following components:

   a. ______________________________

   b. ______________________________

   c. ______________________________

   d. ______________________________

   e. ______________________________

   f. ______________________________

   g. ______________________________

   h. ______________________________

   i. ______________________________

   j. ______________________________

3. Draw lines connecting all components in the Line Voltage Circuit.

4. Draw lines connecting all components in the Control Voltage Circuit.

5. Have the instructor check your work.

Checked by ______________________
Instructor

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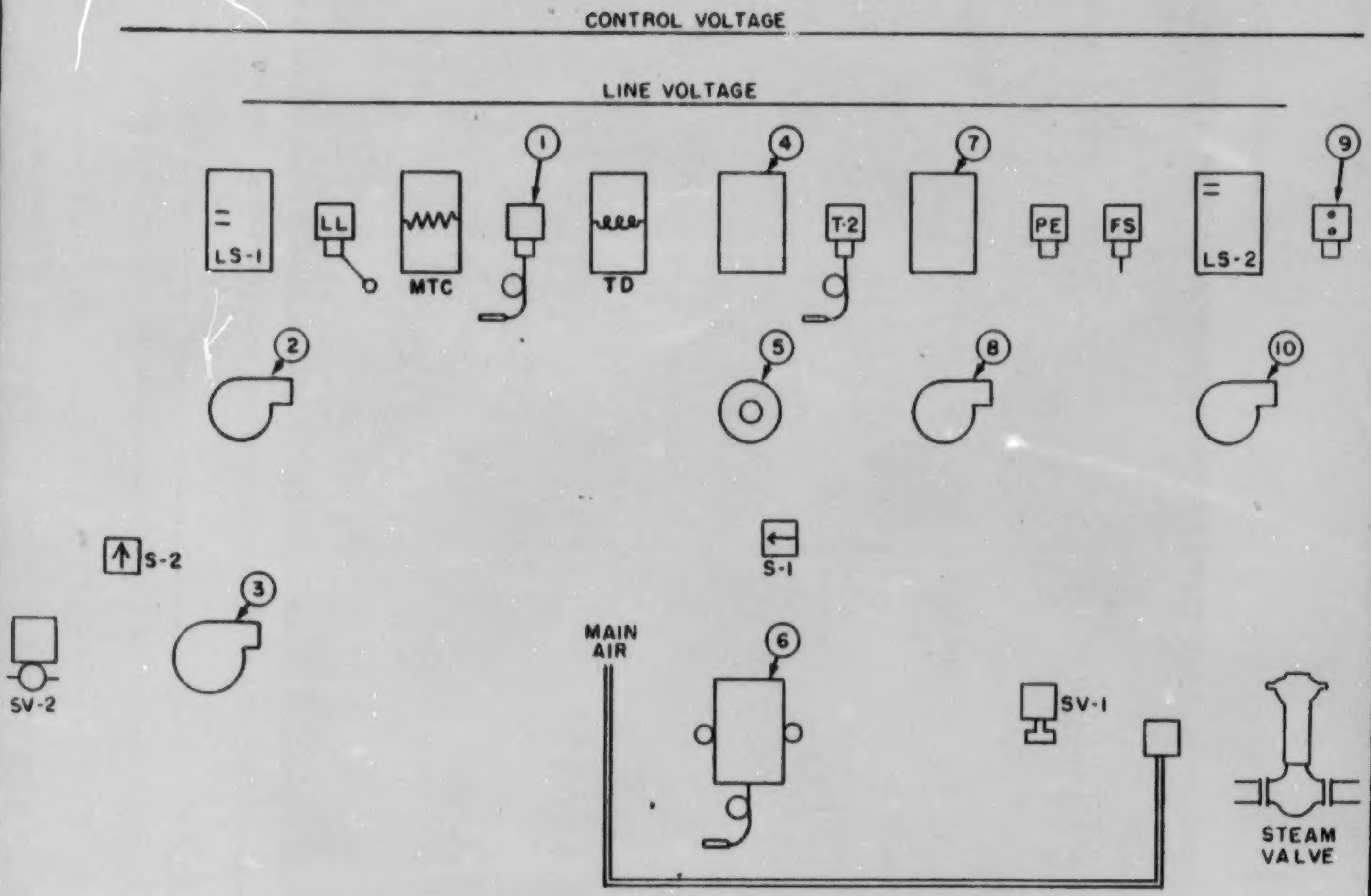
CONTROL VOLTAGE
LINE VOLTAGE
1
4
7
9
LS-1
LL
MTC
TD
T-2
PE
FS
LS-2
2
5
8
10
S-2
S-1
3
SV-2
MAIN AIR
6
SV-1
STEAM VALVE

Figure 11

WB 3ABR54530-VI-6-P7

TROUBLESHOOTING CHART

OBJECTIVE

This project will aid you in using a Troubleshooting Chart and give you experience in using one.

1. Refer to figure 12 and complete the statements below.
2. Each manufacturer of absorption systems publishes an aid to problem solving.

   This aid is a ______________________________.
3. Troubleshooting charts are usually divided into three columns. These columns are labeled:
   - a. ______________________________.
   - b. ______________________________.
   - c. ______________________________.
4. An improperly set capacity control valve can result in the condition called

   ______________________________.
5. Solidification during operation can happen on absorption systems because of

   ______________________________ at the solution pumps.
6. Air inside the machine can result in two conditions. These two conditions are ____________________ and ____________________.
7. A unit solidified at startup because of excess steam pressure. The recommended remedy is to ______________________________.
8. A machine solidified during operation because the cooling tower water was too cold. The suggested remedy is ______________________________.
9. Electrical power was lost just as the dilution cycle was started and the solution crystallized in the heat exchanger. The cause of solidification according to the Troubleshooting Chart is ____________________ __________

   ______________________________.

Checked by ______________________

Instructor

CONDITION	CAUSE	REMEDY
Low capacity	1. Improper refrigerant charge.	Check overflow tube. Remove refrigerant.
	2. Air in machine.	Find leak and repair. Purge the machine.
	3. Solution leaving generator below 220°F at full load.	Raise steam pressure. Unplug steam strainer.
	4. Capacity control valve improperly set.	Reset capacity control valve to design temperature.
	5. Improper purging.	Check operation of the purge unit.
	6. Condenser water temperature too high or small condenser waterflow.	Reset tower bypass control. Check pump operation.
Solution solidifies at startup.	1. Improper purging.	Check purge operation.
	2. Cooling tower water too cold.	Reset cooling tower bypass valve to design temperatures.
	3. Excess steam pressure.	Reset steam regulating valve.
	4. Air inside machine.	Purge the machine.
	5. Poor wetting of absorber tubes.	Add alcohol.
Crystallization of Lithium Bromide solution during operation.	1. Air leakage.	Check unit for leaks.
	2. Seal leakage.	Close seal tank makeup valve. Check seal tank for water loss.
	3. Steam pressure high.	Reset to design.
	4. Condenser water too cold.	Check and reset cooling tower bypass valve.
	5. Dilution cycle less than seven minutes.	Lengthen dilution cycle. Desolidify.

Figure 12

STUDY GUIDE 3ABR54530-VII-1 and 2

Department of Civil Engineering Training

Refrigeration and Air-Conditioning Specialist

AIR COMPRESSING EQUIPMENT AND PNEUMATIC CONTROLS

July 1975

SHEPPARD AIR FORCE BASE

11-8

Designed For ATC Course Use

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(Superseded copies may be used until stock is exhausted.)

Department of Civil Engineering Training
Sheppard AFB, Texas

SG 3ABR54530-VII-1
July 1975

AIR COMPRESSING EQUIPMENT

Page

OBJECTIVE

1 To learn the purpose, principle of operation, and adjustment of air compressing equipment, and pneumatic controls.

5

INTRODUCTION

One of the greatest problems in air conditioning is the control of the cooling and heating effects. Automatic controls are used to solve this problem by sensing and controlling the amount of heating or cooling.

An automatic control system must have some type of energy for operation. Pneumatic controls use compressed air for operation, and electric and electronic controls use electricity for operation. This study guide pertains only to pneumatic controls.

It has been found that the basic control concepts, taken for granted by personnel working in the control industry, are not generally known or understood by the layman.

Fundamentals of Automatic Control

Automatic controls enable man to complete his tasks better and at lower operating cost than if the same work were done with manual controls. Their application is widespread. It would be difficult to enumerate all of the uses of automatic controls, but a few examples are given below to indicate the scope of the subject. Uses range from the simple controls in home appliances and automotive devices through domestic heating and commercial comfort air conditioning to commercial and industrial process controls.

The simple thermostats in the electric flat iron and electric toaster are elementary examples of automatic control. The numerous automatic controls used in water heaters, automatic clothes washers and dryers, and dishwashers suggest somewhat more complicated applications. The electric thermostat which starts and stops the oil or gas burner in the home is well known. Equally important, but not so well known are the various limit and safety controls necessary to the safe operation of the burner.

High speed, precision mass production depends on automatic control. Some of these systems are quite complex. Uniformity of manufacturing conditions and products are essential. Automatic control provides the necessary uniformity. More recent examples of complex automatic control are found in missile launching, tracking and guidance systems.

Among the important fields making use of automatic controls are heating, ventilating and air conditioning. From earliest times, comfort has been a goal of man so that he can live and work at any time in all parts of the world.

First came a crude shelter, later a fire to warm the shelter. Both shelter and heating means gradually improved, but automatic control for regulating heat did not begin to appear until the end of the nineteenth century. Today, we not only expect the places we live and work to be heated, but to be cooled when needed, as well. We expect and get precise comfort conditions with safety and efficiency.

AIR COMPRESSING EQUIPMENT

Air Compressor

The air compressor plays a very important part in pneumatic control systems. Figure 1 shows a typical tank-mounted compressor. A correctly sized compressor should not run more than 50 percent of the time to maintain operating pressure. A thermal overload protection is usually built into the electrical circuit to prevent damage to the system in event the compressor drive motor becomes overloaded.

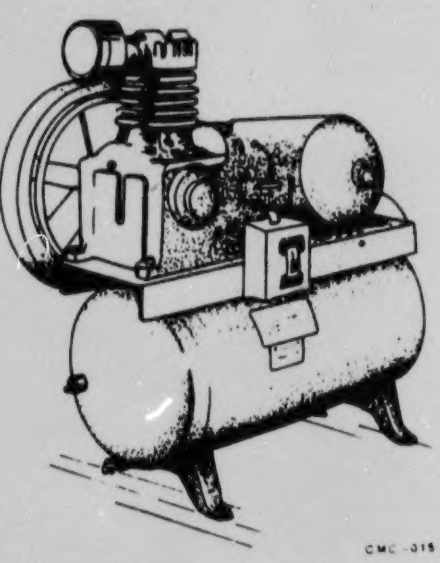


Figure 1. Tank-Mounted Compressor

The air compressor has a suction intake filter to clean the air that goes into the compressor. The compressor pushes the air into the storage tank until the high pressure motor control stops the electric motor that is turning the compressor. When the pressure goes down, the control turns the motor on again. The air leaves the compressor and goes through a filter and on to the pressure-reducing valve which reduces the high pressure to 15-20 psig as required.

PREVENTIVE MAINTENANCE. Although the components of all control systems are of the highest quality available and should give years of excellent service, it is essential that the following procedures be followed, see figure 2.

Outside Air Filter. This should be cleaned each 30 days and replaced at least twice each year. A greater frequency of cleaning and replacement may be required depending on the location of the filter and the amount of dust and dirt in in the air.

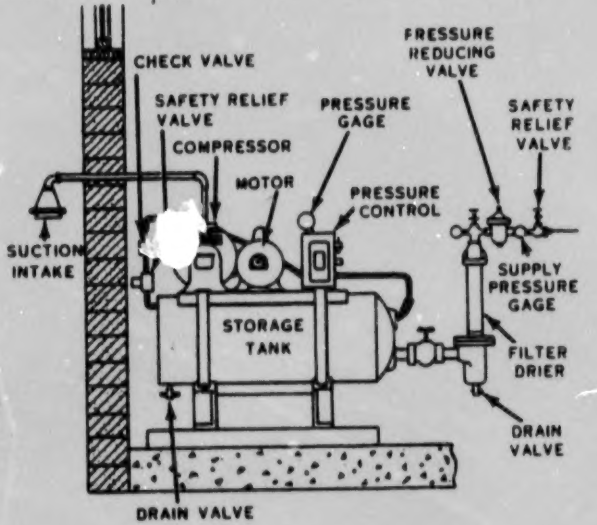

CHECK VALVE
PRESSURE REDUCING VALVE
SAFETY RELIEF VALVE
PRESSURE GAGE
SAFETY RELIEF VALVE
COMPRESSOR
MOTOR
PRESSURE CONTROL
SUCTION INTAKE
SUPPLY PRESSURE GAGE
STORAGE TANK
FILTER DRIER
DRAIN VALVE
DRAIN VALVE

Figure 2. Air Compressing System

Belt Adjustment. Belt tension and condition should be checked every 30 days. The belt should deflect approximately 1/4" with normal hand pressure; if the deflection varies, the motor should be moved accordingly to adjust the tension. Be sure to keep the pulleys aligned.

Oil Level. This must be checked at least once a month and changed every 500 operating hours or as specified by the service bulletin. In all cases use a paraffinic base type oil especially produced for air compressors.

Oil Filters. Large installations require an oil filter to remove the oil carried over from the air system. When properly sized these should be replaced every 90 days. Installations that do not have an oil filter should be inspected weekly. Oil that is dirty or white in color (indicates moisture) should be replaced immediately.

Draining of Air Tank and Air Line Filter. The air tank or tanks should be drained daily. When the outside air is cold and dry, there will be little moisture, but when it is hot and humid, water will collect very rapidly. Do not try to outguess the weather but check regularly.

Reducing Valve Output Pressure. Check pressure daily.

Equipment Cleanliness. Equipment should be kept clean and its operating area kept free from dirt.

Operation. All safety devices, controls, and operating devices should be checked every 30 days for proper operation. Any unusual noises or indications should be investigated and repaired immediately.

Machine Guards. All machine guards on equipment must be secure and checked for security at each inspection.

SUMMARY

Pneumatic controls must be supplied with energy (energy is defined as the ability to do work) before they will operate. This supply of energy is produced and stored in the air compressor assembly. This air must be clean, dry, and supplied in ample amounts. To insure this equality of air we as refrigeration and air-conditioning specialists must maintain the air compressor assemblies to within certain specification. By proper preventive maintenance and periodic checks we can be assured of a supply of air capable of being used by the most sensitive pneumatic controller.

QUESTIONS

1. What purpose does the air compressor assembly serve in a pneumatic control loop?
2. At what component does the air first enter the system?
3. How often should the air compressor's oil be changed?
4. What purpose does the safety relief valves serve in the air compressor assembly?
5. Why should a correctly sized compressor not operate more than 50 percent of the time?

REFERENCES

1. Johnson Service Company Apparatus and Service Bulletins
2. AFM 85-30, Operation and Maintenance of Air Compressors

PNEUMATIC CONTROLS

OBJECTIVE

To learn the purpose, principle of operation, and adjustment of pneumatic controls.

INTRODUCTION

One of the greatest problems in air conditioning is the control of the cooling and heating effects. Automatic controls are used to solve this problem by sensing and controlling the amount of heating or cooling.

An automatic control system must have some type of energy for operation. Pneumatic controls use compressed air for operation, and electric and electronic controls use electricity for operation. This study guide pertains only to pneumatic controls.

It has been found that the basic control concepts, taken for granted by personnel working in the control industry, are not generally known or understood by the layman.

CONTROL TERMS AND THEORY

Control Terms

SUPPLY PRESSURE. The energy source (compressed air) supplied to the controller. It is usually 15 to 20 psig, but in special cases may be some other value. It comes from the tank of the air compressor through a pressure regulating valve, which determines the supply line pressure. Supply pressure enters a controller on the left and is often referred to as MAIN air.

CONTROL SYSTEM. A grouping of instruments that control or regulate a variable (temperature, humidity, or pressure) and maintain it at a predetermined value.

CONTROL LOOP. That part of a system that controls the variable in a specific area.

CONTROLLER. An instrument that measures variations in the controlled variable and produces a corresponding control action. Thermostats, humidistats, and pressurestats are examples of controllers.

CONTROLLED VARIABLE. The variable being controlled. Air temperature, relative humidity, or pressure.

CONTROL PRESSURE. The output pressure from a pneumatic controller. It varies with the controlled variable in a manner determined by the control action. Often referred to as BRANCH pressure.

CONTROL ACTION. Type of action (response) produced by the controller.

Direct Acting. Applies to a controller that increases its control pressure as the controlled variable increases.

Reverse Acting. Applies to a controller that decreases its control pressure as the controlled variable increases.

TWO POSITION ACTION (RESPONSE). Type of control action where the control pressure is either zero or maximum with no intermediate steps. Final device is either ON or OFF, OPEN or CLOSED.

PROPORTIONAL ACTION (RESPONSE). An output signal changing in proportion to the amount of change in the controlled or measured variable. It may be any value between zero or maximum. Final device is in any position between full open or closed.

CONTROLLED DEVICE. The final control element, such as a valve or damper, which is actuated by the controller and regulates the flow or effect of the control agent.

NORMALLY OPEN. A controlled device that automatically assumes an OPEN position when control pressure is removed. It requires pressure to close.

NORMALLY CLOSED. A controlled device that automatically assumes a CLOSED position when control air is removed. It requires pressure to open.

CONTROL AGENT. The medium regulated by the controlled device. Steam, hot or chilled water, brine, etc. These are agents and effect the changes in the controlled variable.

SENSING ELEMENT. That part of a controller that measures the change in temperature, humidity, or pressure and converts this change to movement.

NOTE: The following terms pertain to calibration and adjustment of pneumatic controls. A thorough knowledge of their definition is essential for you to operate and adjust pneumatic controls and insure that proper calibration is accomplished.

DESIRED VALUE. Is the value of the controlled variable (temperature, humidity or pressure) which it is desired to maintain. This is the condition we WANT.

SET POINT. The value of the variable for which the controller is set. It is the target value which the controller attempts to maintain. This is the condition we ASK for.

CONTROL POINT. The actual value of the variable which the controller is maintaining at any given time. This is the condition we GET.

DEVIATION. The difference between the set point and the control point at any given time. When the difference remains constant, it is called offset.

SENSITIVITY. The change or number of psi the controller output changes per unit change in the controlled variable, (psi/degree temperature) (psi percent relative humidity) (psi/psi pressure change). The sensitivity may be fixed or adjustable.

THROTTLING RANGE. The change in controlled variable required to produce full movement of the controlled device or devices.

SPRING RANGE. The range through which the signal applied must change to produce total movement of the controlled device from one extreme position to the other.

Nominal Spring Range. The change in applied signal that causes total movement when there is no external force opposing the operator. It is the range listed in the manufacturer's service bulletin.

Actual Spring Range. The change in applied signal that operates the controlled device under conditions when it must overcome forces due to fluid flow, friction, etc in addition to nominal spring range.

EXAMPLE: An operator has a spring with a range of 8 to 13 psi. The operator will not move until 8 psi is applied and will be fully actuated at 13 psi. This spring has a span of 5 psi i.e. 13 minus 8 equals 5 psi.

It must be noted that spring range, span, throttling range and sensitivity have a direct relationship to each other. This can be seen by the following formula and tables.

Formula: degree temperature change divided into psi span equals sensitivity.

TEMP	OUTPUT	VALVE POSITION
77F	8 psig	Closed
76F	7 psig	1/4 Open
75F	6 psig	1/2 Open
74F	5 psig	3/4 Open
73F	4 psig	Wide Open

1 psi/1 degree

TEMP	OUTPUT	VALVE POSITION
76F	8 psig	Closed
75F	6 psig	1/2 Open
74F	4 psig	Wide Open

2 psi/1 degree

PROPORTIONAL BAND. The change in controlled variable required to move the controlled device from one of its extreme limits of travel to the other. It is normally used in conjunction with recording and indicating controllers and expressed in PERCENT OF THE CHART OR SCALE RANGE (compare to throttling range).

Purpose of Pneumatic Controls

The main purpose of pneumatic controls is to automatically maintain a predetermined condition in schools, office buildings, hospitals, and various places occupied by people and equipment.

Application of Pneumatic Controls

Pneumatic controls are needed when we desire to automatically control temperature, relative humidity, pressure, level, flow, and various other conditions. The primary applications are control of temperature, relative humidity, and pressure.

Pneumatic Control System

To understand the pneumatic control system, it is necessary to understand all the elements that produce the various control effects. While all instrument designers use the same basic elements, their finished products differ considerably in performance, maintenance requirement, and adjustment.

Essentially, a basic control system consists of a controller, an operator, a controlled device and the energy source necessary for the operation of these devices. For example, the controller may be a room thermostat, the operator may be a damper operator, and the energy source compressed air. More complex systems are simply a group or groups of suitably coordinated basic control systems. Controls can be classified according to source of energy and function.

A typical control system is shown in figure 3.

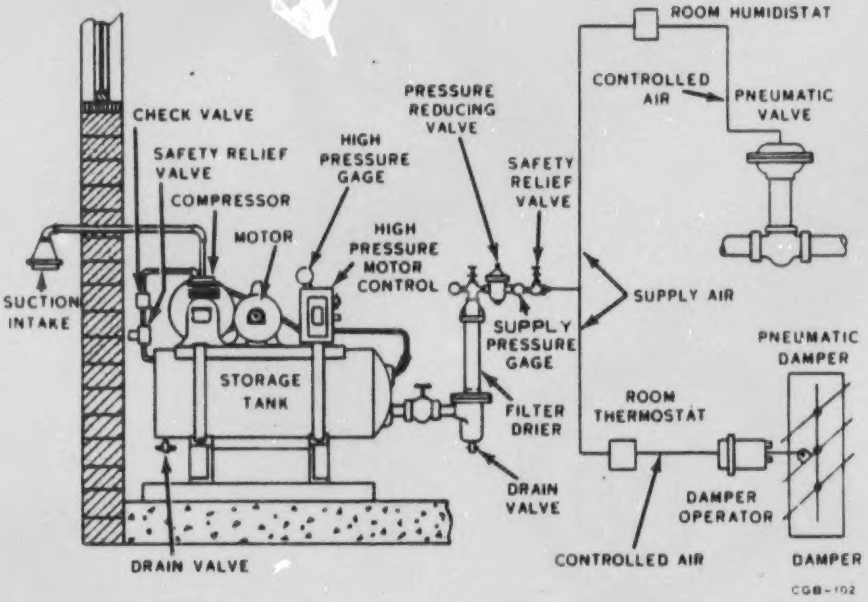

ROOM HUMIDISTAT
CONTROLLED AIR
PNEUMATIC VALVE
PRESSURE REDUCING VALVE
CHECK VALVE
HIGH PRESSURE GAGE
SAFETY RELIEF VALVE
SAFETY RELIEF VALVE
COMPRESSOR
MOTOR
HIGH PRESSURE MOTOR CONTROL
SUCTION INTAKE
SUPPLY AIR
SUPPLY PRESSURE GAGE
PNEUMATIC DAMPER
STORAGE TANK
FILTER DRIER
ROOM THERMOSTAT
DRAIN VALVE
DAMPER OPERATOR
DRAIN VALVE
CONTROLLED AIR
DAMPER
CGB-102

Figure 3. Control System

CONTROL LOOP. All automatic control systems have a common pattern which recognizes the relationship of "cause and effect," that is, the interdependence of one thing upon another. This is commonly called "feedback." Feedback makes true automatic control or self-regulation possible. The following examples clarify this point.

In figure 4, the room thermostat (TR) measures the temperature of the air surrounding it. As the temperature rises, the thermostat causes a reduction of the heat input (HI) to the room, which allows the room temperature (RT) to stop rising or to drop. This, in turn, affects the thermostat, which readjusts its influence and on heat input until a balance is stabilized. Thus, one change is dependent upon another and a "closed loop system" has been established.

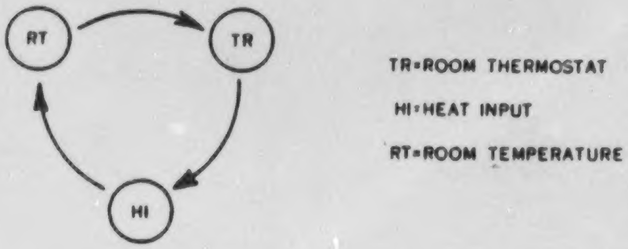


Figure 4. Closed Loop System

There are three basic parts which must be considered when putting together a closed loop system. They are:

The Control Agent. This source of energy supplied to the system can be either hot or cold, such as steam, hot water, heated air, chilled water or chilled air.

The Controlled Device. A valve or damper can be either Normally Open or Normally Closed to regulate the flow of the Control Agent. It is chosen primarily for "failsafe" operation.

The Controller Action. A controller is furnished with either Direct Action or Reverse Action. This will allow the balance mentioned above.

The proper combination of these three parts must be applied or the Closed Loop System will not operate.

PNEUMATIC CONTROLLERS

The pneumatic controller is an instrument that measures the temperature, humidity, and pressure, or varies the control pressure to the final controlled device as a correction is needed. The controller must have a measuring element to sense changes in the temperature, humidity, or pressure and then convert it into mechanical movement. The mechanical movement will cause another part of the controller to change the control pressure going to the final controlled device.

Bleed Controls

The simple bleed control system shown in figure 5 is an example of an automatic control accomplished with compressed air.

Air from the source (air compressor), after it has been reduced, is fed through a restrictor or small orifice, to a leakport. The restrictor opening is smaller than the opening in the leakport. Because of the difference in size of the openings, the pressure will reduce after it passes the orifice. With the lid moved away from the leakport as in figure 5 you can see that the gage to the valve reads 0 psi.

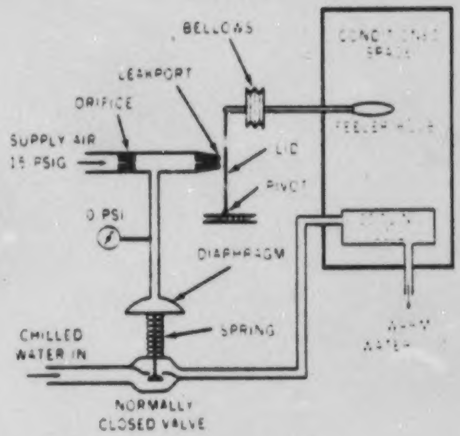


Figure 5. Simple Bleed Control Principle

A temperature increase causes the lid to move closer to the leakport and this movement reduces the amount of air bleeding from the leakport. The air continues to flow through the restrictor, and since the bleeding is reduced, the valve pressure increases. The valve opens and causes the temperature to be lowered.

A decrease in temperature causes the lid to move away from the leakport, and more air can bleed to the atmosphere. Since the restrictor only allows so much airflow, the pressure will decrease. This decrease in pressure allows the valve to move toward the closed position, reducing the amount of cooling for temperature control.

Do you know why this control is called a bleed type? Think for a minute: can the leakport and the lid make a positive seal? Does the orifice change in size? NO. Therefore, in a bleed type the air bleeds to the atmosphere constantly.

A two-position controller is an instrument that provides a full output signal, or no output signal, with no intermediate steps. It is also known as an "On-Off" or snap controller.

The controlled device can be a valve or damper operator which will be either fully open or fully closed, depending on the signal from the two-position controller. A spring in all controlled devices is under tension at all times and will return the controlled device to its normal position when the controller's signal is removed. See figure 6.

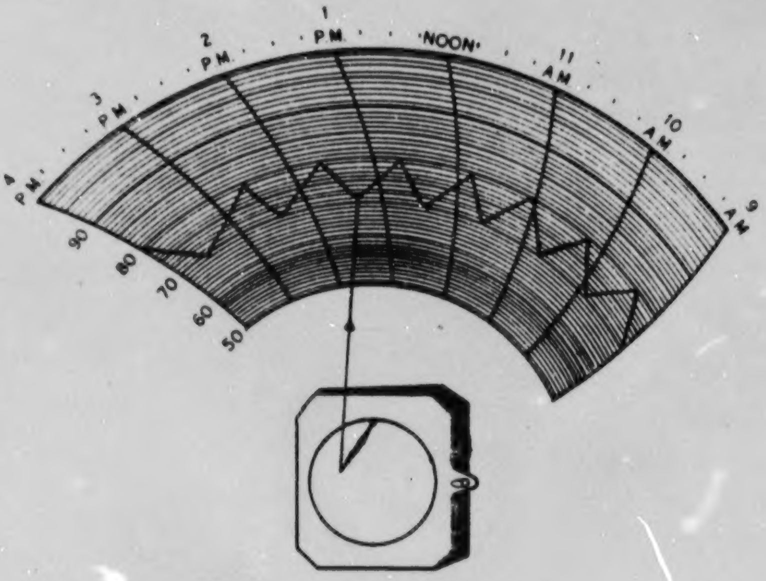


Figure 6. Response of a Two-Position Controller

A proportional controller is an instrument that produces an output signal in direct proportion to a change in input (controlled variable). The output signal of a proportional pneumatic controller can vary from 0 psig to the maximum pressure supplied to the system. Most controllers can be adjusted to vary their output pressure for a given change in the controlled variable. This is referred to as "sensitivity." See figure 7.

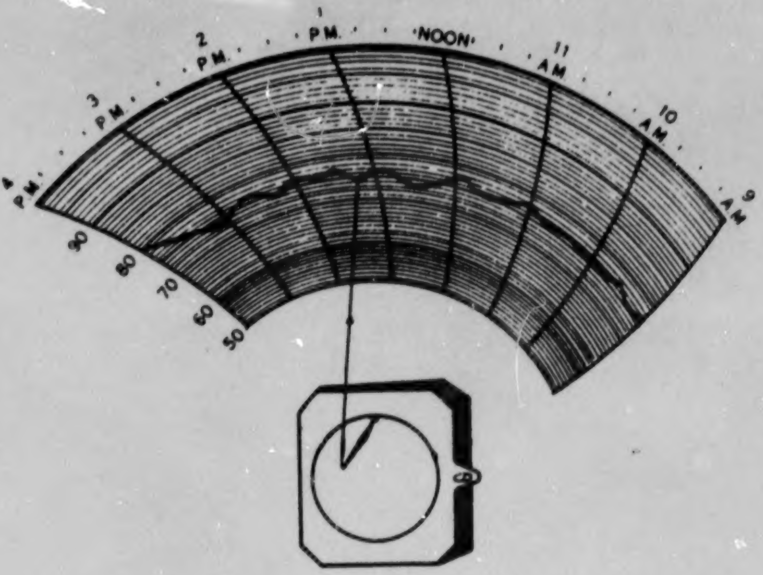


Figure 7. Response of a Proportional Controller

We have discussed the simple bleed type controllers, and you have seen how the pressure is changed. The simple bleed control is not as accurate as it is desired in some controls, such as the pneumatic controllers that we will discuss later.

For a more accurate control, most controllers use a pneumatic relay.

The standard proportional pneumatic relay is a device designed to be supplied with a constant supply pressure, and uses a small quantity of this air to control a large volume of output air at any pressure between zero and full supply air pressure. The small quantity of air that determines the output air pressure is called pilot air. It is a small portion of the supply air admitted to the pilot chamber through a pin valve restrictor set for 5" water gage pressure with the pilot chamber open to atmosphere, i.e., with the control port wide open. Pilot air pressure varies with the quantity of air passed through the control port. The quantity passed is controlled by a movable lid usually regulated by the element measuring the value of a controlled variable. Thus the output pressure varies in proportion to changes in the controlled variable. Proportional relays are of two types:

DIRECT ACTING. A relay that increases output pressure when pilot air increases, figure 8.

REVERSE ACTING. A relay that decreases output pressure when pilot air increases, figure 9.

OPERATION. Both direct and reverse acting relays have a cone-shaped valve that serves a dual function. The cone closes against both the main valve seat and the exhaust valve seat.

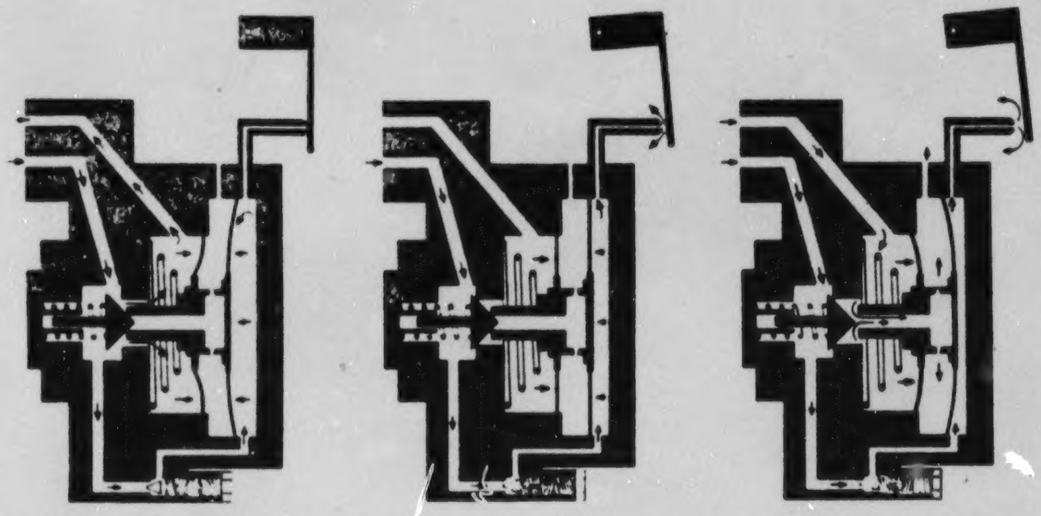
In its main valve function, the cone is normally closed against the opening between the supply air passage and the control air chamber. The exhaust valve action is in the opposite direction.

The exhaust valve opening, a part of the internal mechanism, moves toward the cone, seating on the cone surface between the main valve seat and the tip of the cone.

Direct Acting Relay

As shown in figure 8A, partially closing the control port causes the pilot pressure to increase and move the pilot diaphragm and spring-loaded internal mechanism so that the exhaust valve seats on the main valve cone. This closes the control chamber to atmosphere. This action continues and the spring-loaded main valve is forced open, allowing supply air to pass through the control line. Since this is a closed line, pressure increases and acts against the control diaphragm, thus opposing the movement caused by the increasing pilot pressure.

BALANCED CONDITION. As shown in figure 8B, when pilot pressure stops changing, the control pressure increases until the combined force of the springs and control diaphragm equals the opposing force from the pilot diaphragm. The main valve is held tightly closed by its spring and the exhaust valve is also closed against the main valve cone. The relay is now in a balanced position as shown in figure 7B. No air enters or leaves the control chamber and output pressure remains constant.



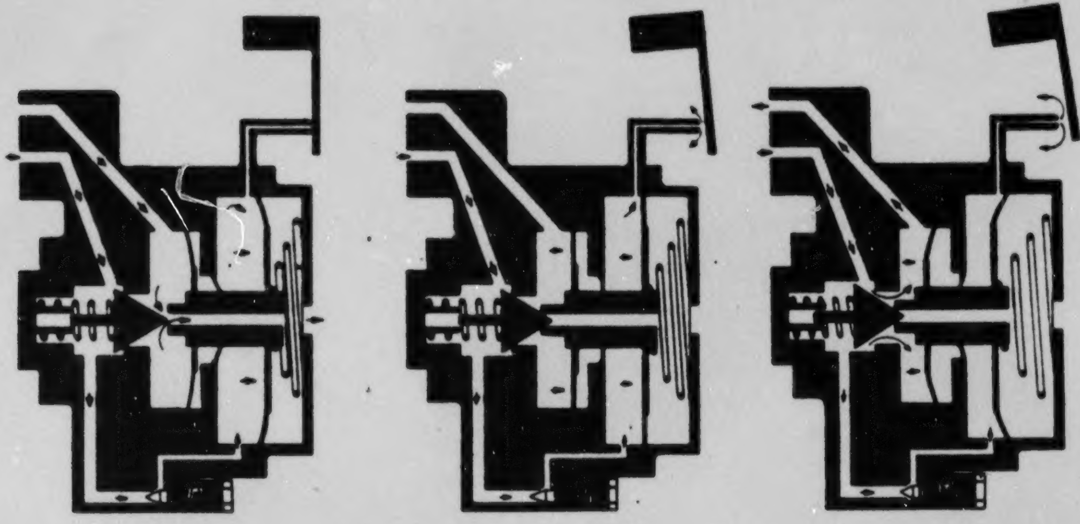
A INCREASING PRESSURE B BALANCED POSITION C DECREASING PRESSURE

Figure 8. Direct Acting Proportional Relays

DECREASING PRESSURE. Opening the control port as shown in figure 8C, causes the pressure in the pilot chamber to decrease. This causes the internal mechanism and exhaust valve to move away from the main valve cone which remains seated and allows the air in the control chamber to pass through the open exhaust valve and escape to atmosphere through the exhaust port. The decreasing pressure in the control chamber reduces the pressure on the control diaphragm until the exhaust valve closes and the relay is again in balance.

Reverse Acting Proportional Relays

The reverse-acting relay is similar to the direct-acting relay except that the pilot pressure is applied to the opposite side of the pilot diaphragm and its direction of operation is opposite. A third diaphragm is added between the pilot and control diaphragms to act as a seal to maintain atmospheric pressure in the center chamber. See figure 9.



A INCREASING PRESSURE

B BALANCED POSITION

C DECREASING PRESSURE

Figure 9. Reverse Acting Proportional Relays

A spiral spring with adjustable compression opposes movement of the internal mechanism. The spring compression and its resultant force in the reverse-acting relay determine the amount of pilot pressure required to start the main valve moving toward its seat. The main valve is normally open and the exhaust valve is normally closed. All diaphragms are attached to the internal mechanism and the exhaust passage through the internal mechanism discharges its air into the spiral spring chamber formed by the pilot diaphragm and the spring housing. A hole in the center of the housing allows the air to escape to atmosphere when the valve is open.

INCREASING PILOT PRESSURE. On an increasing pilot pressure, figure 9A, the pilot diaphragm overcomes the spring force to move the internal mechanism toward the spiral spring. This action allows the main valve spring to close the main valve. As this movement continues, the exhaust valve passage opening moves away from the main valve cone allowing the control air to escape through the passage to atmosphere. This reduces the pressure in the control chamber until the control air is completely exhausted or a balanced condition is reached as shown in figure 9.

The relay we have been discussing uses a cone-shaped valve to control the output of the controller. The controllers we will use in the classroom are of the flapper type. All operating theory remains the same except the cone is replaced with a flapper which is not as subject to vibration and also the relay has a fixed restrictor which is set at 5 inches water gage. See figure 10.

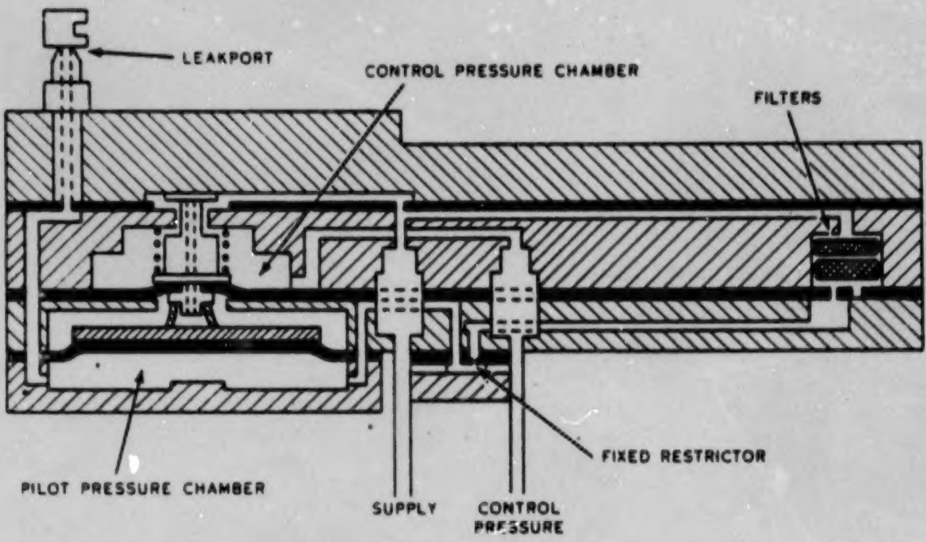


Figure 10. Flapper Type Relay

PNEUMATIC VALVE

The pneumatic valves are designed for precise regulation of water or steam flow through heating or cooling equipment in response to demand signals from a pneumatic controller. Valves are offered in a wide range of standard sizes and capacities to meet any requirements, and in a variety of body patterns and connections to allow flexibility of application. However, there are only three basic body styles and all patterns fall into one of these styles: normally-open, normally-closed and three-way. The normally-open valve will close when air pressure from the controller is applied to the diaphragm. A normally-closed valve will open when the air pressure from the controller is applied to the diaphragm.

The third type is the three-way valve. This may be called a mixing, a diverting, or a bypass valve. There are three connections on this type, common, normally open, and normally closed. The mixing valve has two inlets and one common outlet. Air pressure from the controller regulates the inner valve so that the entire flow is from either one of the two inlets or a portion from both. Bypass or diverting valves have one inlet and two outlets. The flow is directed to either one of the two outlets when air pressure from the controller is applied to the valve operator. Any portion of the flow can be directed to both outlets by an intermediate air pressure in the operator.

In the operation of the pneumatic valve, air pressure from the controller enters the diaphragm chamber. The pressure rise in the chamber causes the diaphragm to push the plate down against the spring. The spring is compressed, and the valve disk or plug is moved against or away from the valve seat, depending on whether it is a normally open or normally closed valve. The valve should be installed to close against the flow to prevent the flow from slamming it shut.

The amount of pressure required to move the valve from open to close is the spring range. The spring range of a valve can be determined by applying pressure to see when the valve starts moving and when it has moved as far as it will go. If the valve starts moving at 7 psig and completes its move at 11 psig, the spring range is 7 to 11 psig. The midspring range is used in the calibration of a controller, so it is important to understand this term.

The midspring range between the high and low psig of 11 and 7 is 9. This midspring range can be determined by adding the high and low, and dividing by 2 (11 + 7 = 18 and 18 ÷ 2 is 9). When the controller sends 9 psig to the diaphragm, the pneumatic will be positioned half open.

The different components of a pneumatic valve are shown in figure 11. As stated before, the controlled device consists of the pneumatic operator and the unit (valve) that controls the flow of the control agent. The parts that form the operator are the top, diaphragm, diaphragm plate, spider with setscrews, stem extension, spring plates, spring and yoke. The parts of the valve are the body, bonnet, disk or plug, and the seat.

The rubber diaphragm operator has a molded reinforced rubber diaphragm enclosed in a strong metal housing for protection against dirt and damage. This operator is available in four sizes and can be used on valves up to eight inches in size. The entire operator can be removed by loosening three screws.

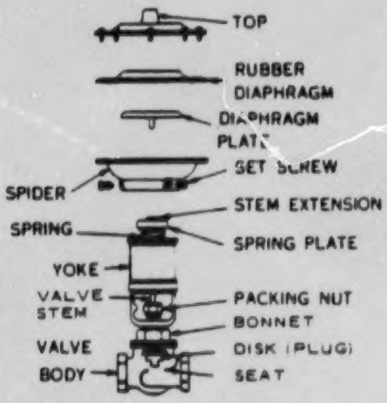


Figure 11. Components of Pneumatic Valve

DAMPER OPERATORS

Damper operators are used to control the flow of air, its operation is similar to that of the pneumatic valve.

The majority of damper operators are of the piston type. This operator has a long powerful straight stroke which requires no lever arrangements.

Air from the controller is applied to the molded diaphragm which has a positive seal to prevent leakage, figure 16. This air pressure expands the diaphragm forcing the piston and stem outward against the force of the spring. The movement of the piston varies proportionally with the air pressure applied to the diaphragm. This air pressure, from the controller, varies over the full pressure range.

The spring returns the operator to its normal position when the air pressure is removed from the diaphragm. Full movement of the operator can be restricted to set limits by using various spring ranges. The most common spring range is 5 to 10 psi. With this spring the operator is in its normal position when the air pressure applied to the diaphragm is 5 psi or less. Between 5 and 10 psi the stroke will be proportional to the air pressure in the diaphragm. Above 10 psi the operator will be at its maximum stroke.

Piston operators can be mounted on the damper frame and coupled directly to the damper blades. In some cases the operator is mounted on the duct work and coupled to the damper blade axis through a crank arm and linkage arrangement. Reversal of the action of the operator on the damper is obtained by mounting the operator in the opposite direction.

Dampers

There are many sizes and styles of dampers each depending on the installation and purpose. However, there are four basic types. Figure 12 shows a proportioning type with the blades rotating in the opposite direction. A damper with parallel blades is shown in figure 13. A mixing damper can be seen in figure 14. Figure 15 is a volume damper. Depending on the function of the damper the blades may be normally open or normally closed. The mixing damper, figure 14, has one set of blades normally open and the other set normally closed.

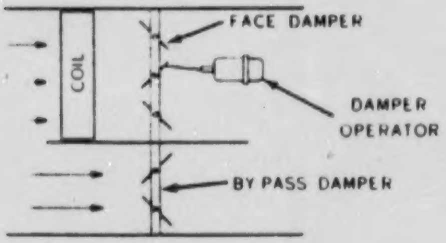


Figure 12. Face and Bypass Damper

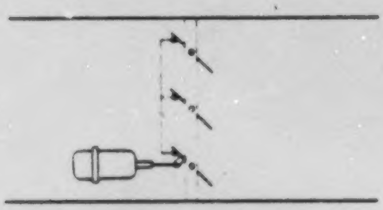


Figure 13. Damper with Parallel Blades

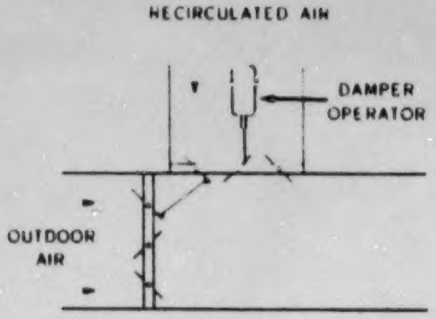


Figure 14. Mixing Damper

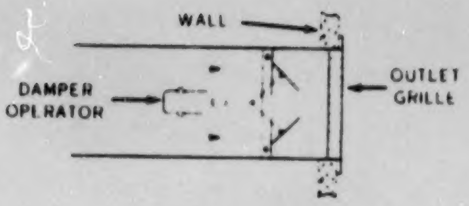


Figure 15. Volume Damper

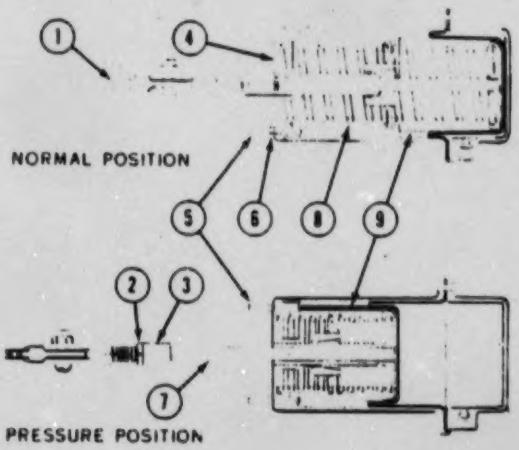


Figure 16. Positions of Piston Operator

All sizes of piston type operators are provided with adjustable stops for limiting the stroke of the operator in the "normal" position, as well as in the "pressure" position. The latter is the position which the operator assumes when full air pressure is applied to it. When a piston type operator is attached to a damper or other controlled apparatus, it is very important that these stops be adjusted properly, as the incorrect adjustment of stops may cause damage to the damper operator or the damper, due to the great power of the piston type operator. Figure 16 indicates the piston type damper operator with the piston in the two extreme positions of the stroke, the "normal" position, which the piston assumes when air pressure is exhausted, and the "pressure" position, which the piston assumes when full air pressure is applied. Referring to figure 16, stop nut "3" is screwed on piston rod "7" and is locked in place by locknut "2." The piston is in the normal position and the force of spring "8" pulls stop nut "3" tightly against cap "4" of the damper operator. Therefore, stop nut "3" provides the normal position limit of the stroke of the damper operator. By screwing stop nut "3" in or out, the "normal" position limit of the stroke can be adjusted.

When air pressure is applied, piston "9" moves outward against the tension of spring "8," until the end of the piston strikes stop screws "5." Stop screws "5" are screwed into cap "4" and provide the pressure limit of the stroke of the damper operator. They are locked in place by nuts "6." By screwing stop screws "5" in or out, the pressure position limit of the stroke also can be adjusted. As stated above, the correct adjustment of the stops is very important. In the fully open or the fully closed position of the damper blades, the travel of piston "9" must be stopped by screws "5" or nut "3," and not by the damper.

For example, as the blades of a normally open damper approach their closed position, the end of piston "9" approaches stop screws "5." If stop screws "5" are screwed out too far, the damper will be closed before piston "9" has reached screws "5." The damper, being fully closed, will prevent piston "9" from moving further and the full force of the air pressure will be transmitted through piston rod "7" and connecting rod "1" to the damper blade. This puts a great strain on the rods, as well as on the damper blades and may bend these parts out of shape. For correct adjustment, stop screws "5" should be screwed in so that the end of piston "9" seats against these screws at the moment when the damper blades reach the closed position. Piston "9" then cannot move further, and no strain is put on rods "7" and "1." The force of the air pressure acts against stop screws "5," and these screws are designed to carry the force safely. It is also important that both stop screws "5" be screwed in an equal distance. Otherwise, piston "9" will rest against only one of the stop screws, and the air pressure will tend to tip the piston.

If stop screws "5" are screwed in too far, they will stop piston "9" before the damper has closed fully, and this will prevent the damper from closing completely.

Stop nut "3," which limits the travel of piston "9," at the other end of the stroke, must likewise be adjusted carefully. The proper adjustment of this nut is determined by consideration similar to those explained above.

Therefore, the adjustable stops which limit the travel of piston "9" at either end of the stroke should be adjusted so as to permit a full 90 degree movement of the damper blades, yet they must prevent the damper operator from putting any strain on the linkage or on the damper blades, when the damper is fully closed of wide open. To do this properly, the stops must be adjusted so that piston "9" reaches the stop at the same time that the damper blades reach the closed or open positions, respectively. If the stops are screwed in too far, they will not permit the damper to open or close completely. Vice versa, if they are screwed out too far, they will not stop the piston in time to prevent the damper operator from putting strain on the connecting rods.

Spring Ranges

The control pressure range in which piston type damper operators operate is determined by the characteristics of springs "8." A number of different springs are available. The springs for the various ranges of a certain size operator are all of the same outside diameter, are compressed to the same length when assembled in the operator and therefore are interchangeable.

Lubrication

Piston rod "7" which slides in a long bearing which is part of cap "4" is covered in the factory with a lubricating film and needs no further lubrication. No oil should ever be applied to this rod, for if oil should find its way to the rubber diaphragm, it might deteriorate the rubber.

PILOT POSITIONER

A pilot positioner is a relay applied to the operator of a controlled device, which permits maximum and accurate positioning of the controlled device. Friction to movement of the controlled device can be overcome by using a pilot positioner. The accurate control, possible only with the pilot positioner, is obtained by maintaining a balance between the control pressure (now called pilot pressure) from the controller and the position of the stem of the controlled device, acting on a spring.

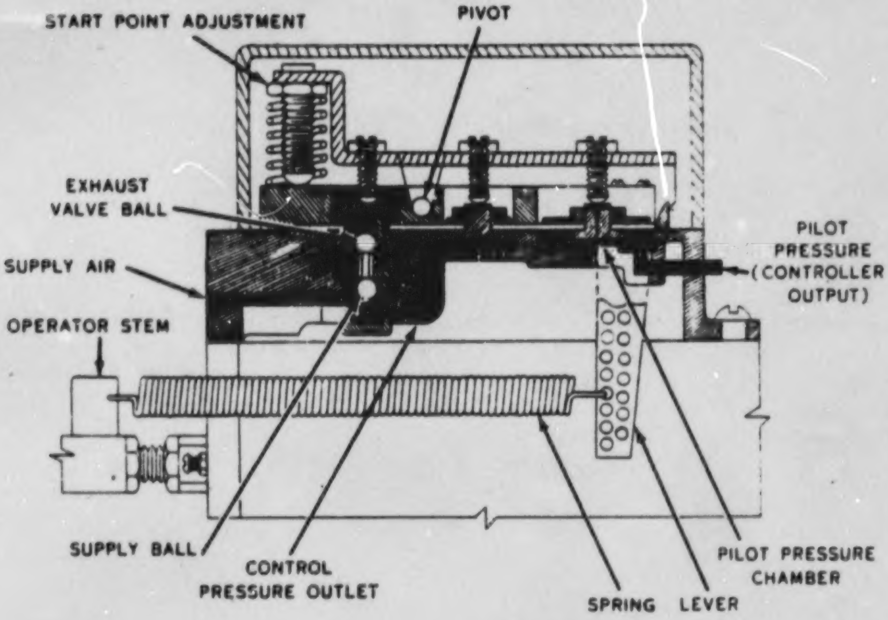

START POINT ADJUSTMENT
PIVOT
EXHAUST VALVE BALL
SUPPLY AIR
OPERATOR STEM
PILOT PRESSURE (CONTROLLER OUTPUT)
SUPPLY BALL
CONTROL PRESSURE OUTLET
SPRING
LEVER
PILOT PRESSURE CHAMBER

Figure 17. Pilot Positioner.

A cross section of the pilot positioner is shown in figure 17. The controller pressure enters the pilot chamber and causes it to expand upward when the pressure rises. The upward motion is transferred to the lever which rotates above the pivot. The other end of the lever is forced down against the exhaust valve assembly. The downward motion closes the exhaust valve and pushes the supply valve open. The supply pressure begins running into the control pressure chamber and out of the outlet to the valve. If the valve moves and stretches the spring, it cancels or equals the pilot pressure and the relay is balanced (supply and exhaust closed). If the stem does not move (due to friction, etc), the relay keeps adding pressure until it does move to the right position.

A drop in the controller pressure will cause the pilot chamber to collapse, since the spring is pulling the lever against the chamber. The other end of the lever lifts up and the exhaust valve opens. The control pressure begins running out of the control pressure chamber to the atmosphere. The operator stem will move back and the lesser spring tension will cancel the smaller pilot pressure and once again the relay will be in balance.

The balancing and unbalancing of the pilot pressure against the spring tension governs the operation of the pilot positioner.

Various conditions can cause inaccurate positioning of the valve. When these conditions exist, the controller cannot move the valve to the right position. The controller sends the correct amount of pressure, but the resistance to movement keeps the valve from moving to the right position. The valve positioner (see figure 18) will make the pneumatic valve go the proper position.

The pneumatic damper can also have corrosion on damper linkages and opposition to movement due to airflow through the dampers which hamper the correct positioning of the damper. The damper positioner (see figure 19) insures that the damper moves to the position called for by the controller.

Valve and Damper Positioners

The pilot positioner is applicable on a pneumatic valve or a pneumatic damper. These two applications are shown in figures 18 and 19.

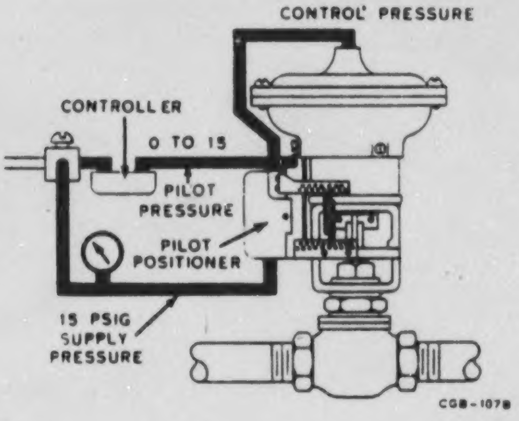


Figure 18. Pilot Positioner on a Pneumatic Valve

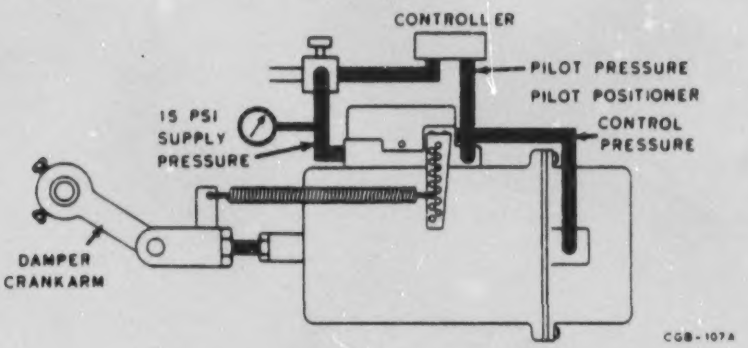


Figure 19. Pilot Positioner on a Pneumatic Damper

The adjustment of a pilot positioner is an important part of your job. Precise positioning of the final control device is impossible if the positioner is not properly adjusted. The method of adjustment is as follows.

Operating Range

The operating range is determined by the span and starting point adjustments of the pilot positioner. The lower value of the range is the pilot pressure at which the operator begins its stroke. The upper value is the pilot pressure at which the operator reaches its maximum stroke. The difference between the upper value and lower value is the operating span.

Operating Span

The operating span is adjustable from 4 to 13 psi. It is established by placing one end of the pilot spring into the hole in the lever arm which corresponds to the desired span. When attached to the inner end of the arm the spring allows a span of 4 psi. At the other end of the lever arm the span is 13 psi.

Starting Point

The starting point, which is adjustable from 1 to 12 psi, is the point at which the operator begins its stroke. It is established by adjusting the screw located under the cover. Turning the screw Clockwise decreases the starting point and Counterclockwise increases the starting point.

On all of the piston operators, the distance between the pilot spring clips, on the operator stem, and the pilot spring lever, on the positioner, is adjustable by turning the connection head on the operator stem. This distance should be such that the pilot spring is just at its free length. The nominal values of these dimensions are shown in figure 20.

SIZE OF OPERATOR	DIMENSION "A"
3" DIA.	4-3/4"
4" DIA	4-7/8"
6" DIA	5-7/8"

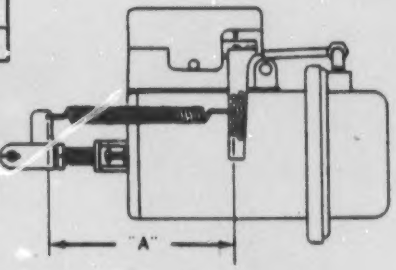


Figure 20. Pilot Spring Data for Pilot Positioner On Damper Operators

ROOM THERMOSTATS

A room thermostat is a device that measures the temperature of an individual room. The thermostat converts the temperature changes into an air pressure (control pressure) that is sent to a controlled device (valve or damper). The controlled device regulates the flow of the control agent (chilled water, hot water, steam, etc) which will control the temperature.

The room thermostat can be used to automatically control the temperature for heating or cooling, but only one at a time. An application for cooling is shown in figure 21. The room thermostat is installed on a wall where it will sense the temperature of the room. The room thermostat modulates the chilled water valve to control the temperature of the supply air. The room thermostat can be applied for heating as well as cooling.

The operation of the room thermostat is very similar to the operation of the basic pneumatic relay. The room thermostat has some type of sensing element. The one you will adjust has a bimetallic element. When the room temperature increases, one side of the bimetal expands faster than the other, so that the element bends. When the temperature increases on a direct-acting thermostat, the bimetal element bends down. When the temperature on a direct-acting thermostat decreases, the bimetal element bends up.

The opening and closing of the leakport causes the pilot pressure to increase or decrease. If we assume that the thermostat is reverse acting, a rise in temperature will cause a decrease in pilot pressure. The control pressure decreases proportionally to the rise in temperature, and the controlled device moves proportionally. This control has a pneumatic feedback which provides proportional control.

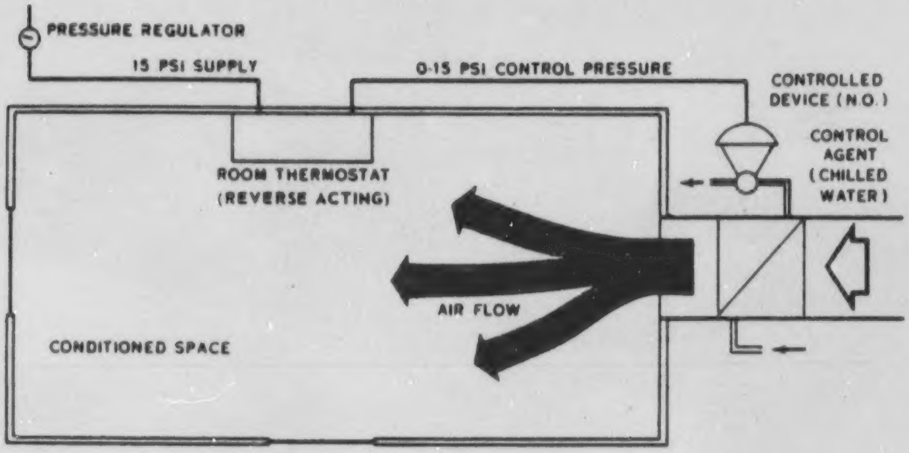

PRESSURE REGULATOR
15 PSI SUPPLY
0-15 PSI CONTROL PRESSURE
CONTROLLED DEVICE (N.O.)
CONTROL AGENT (CHILLED WATER)
ROOM THERMOSTAT (REVERSE ACTING)
AIR FLOW
CONDITIONED SPACE

Figure 21

The Johnson T-4002 room thermostat, figure 22, is a single temperature instrument employing pneumatic feedback for extremely accurate proportional control.

Specifications

Model	T-4002
Action	Proportional, Direct or Reverse Acting
Element	Bimetal Strip
Dial Range	55° F to 85° F
Dial Graduations	One Degree Divisions, Spaced Equally Over Entire Range
Sensitivity	Adjustable 1 to 8 psi/Deg F
Maximum Supply Pressure	25 psi
Relay	Flapper Type

Operation

DIRECT ACTING INSTRUMENT. On a rising ambient temperature the bimetal element bends toward the control port. This causes the relay pilot chamber pressure to increase. The increasing pressure actuates the instrument relay, allowing supply air to flow to the control line, thereby increasing the control pressure. Control pressure acting on the feedback diaphragm causes the lever to rotate away from the control port, establishing an exact output pressure corresponding to the temperature measured by the bimetal element.

On a decreasing ambient temperature the bimetal element bends away from the control port, allowing the relay pilot chamber pressure to escape through it to the atmosphere. This decreasing pilot pressure actuates the instrument relay, allowing the control and feedback chamber pressures to simultaneously decrease. The decreasing pressure on the feedbcck diaphragm causes the lever to rotate toward the control port and output pressure is varied in proportion to the ambient temperature change measured by the bimetal element.

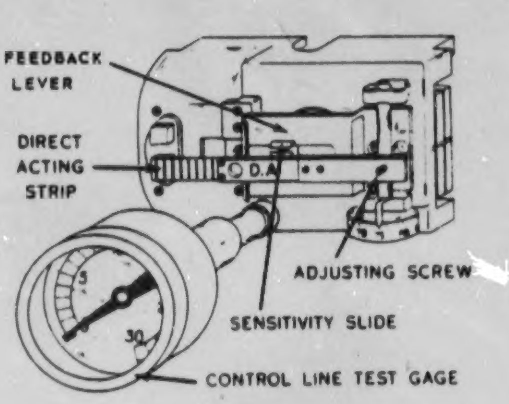


Figure 22. Single Temperature Room Thermostat

REVERSE ACTING INSTRUMENT.

The operation of a reverse acting instrument is similar to the direct acting thermostat except that the direction of change in control air pressure is reversed. A rising ambient temperature causes a decrease in control air pressure and a decreasing ambient temperature causes an increase in control air pressure.

The relay used in this instrument is the flapper type, figure 23.

Temperature Measuring Elements

TEMPERATURE. Temperature measuring elements are made in various types to fit the several kinds of controllers. Wall-mounted thermostats normally use bimetal or vapor-filled bellows elements. Remotely mounted or external elements have liquid, gas or refrigerant filled bulbs and capillaries. The capillary or connecting section on bulb types is furnished in various lengths to allow the controller to be mounted away from the measured variable.

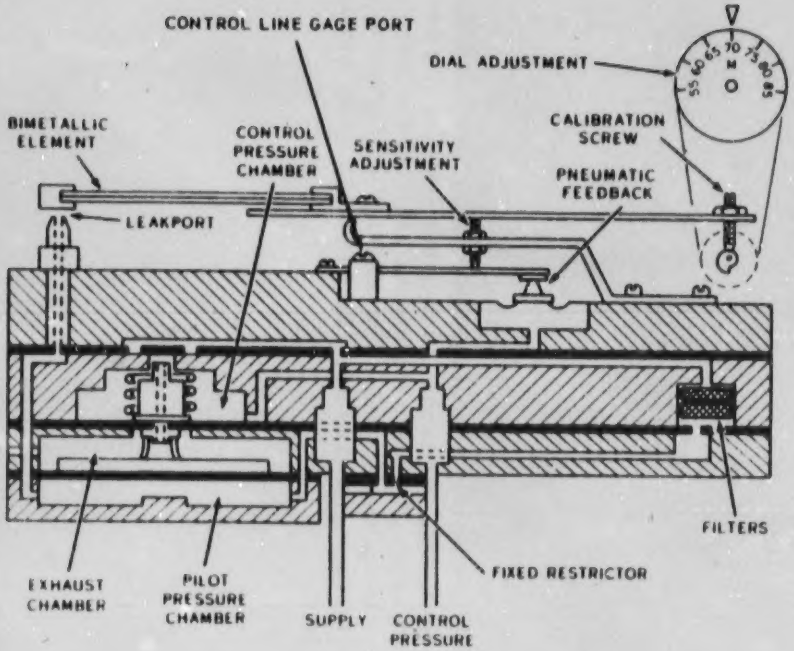
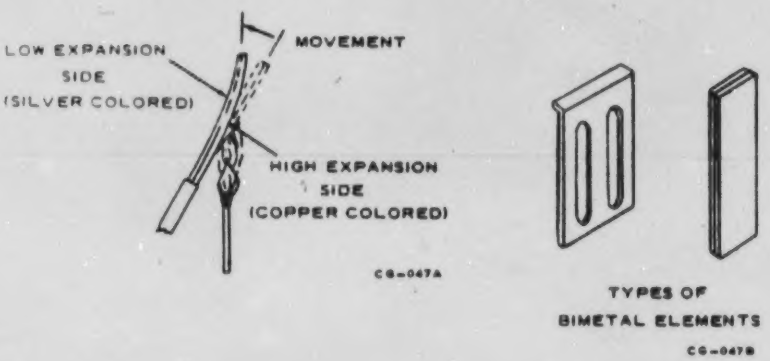

CONTROL LINE GAGE PORT
DIAL ADJUSTMENT
55 60 65 70 75 80 85
M
BIMETALLIC ELEMENT
CONTROL PRESSURE CHAMBER
SENSITIVITY ADJUSTMENT
CALIBRATION SCREW
PNEUMATIC FEEDBACK
LEAKPORT
FILTERS
FIXED RESTRICTOR
EXHAUST CHAMBER
PILOT PRESSURE CHAMBER
SUPPLY
CONTROL PRESSURE

Figure 23. Single Temperature Room Thermostat

Bimetal Elements. Are two thin strips of dissimilar metal fused together to form a device which reliably changes its shape at a constant rate as its ambient temperature changes, figure 24. Because the two metals bonded into one piece expand and contract at vastly different rates, the measuring element bends as the temperature varies, thus translating temperature into motion. Brass is frequently used as the metal with the higher coefficient of expansion. It may be bonded to invar metal (a nickel steel alloy) which does not change dimensions in any direction to any significant degree as its temperature varies. When the ambient temperature rises, the bimetal strip bends toward the metal which makes little or no response to temperature. This unresponsive portion of the element provides the stability factor which makes bimetal strips usable as temperature measuring elements.


LOW EXPANSION SIDE (SILVER COLORED)
MOVEMENT
HIGH EXPANSION SIDE (COPPER COLORED)
CG-047A
CG-047B

TYPES OF BIMETAL ELEMENTS

Figure 24

Remote Bulb Elements. Are used when temperatures are to be measured in tanks, pipes, ducts, or other inaccessible locations. These elements have three parts: the bulb, or temperature sensitive portion; the capillary, which transmits the variable temperature signal over its length; and the diaphragm or operating head, which translates the signal into movement, figure 25.

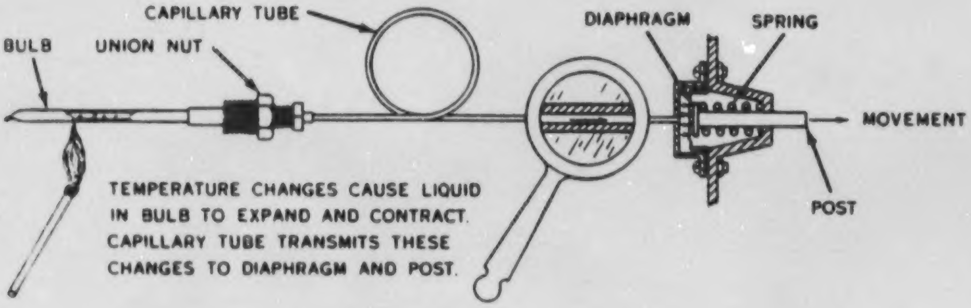
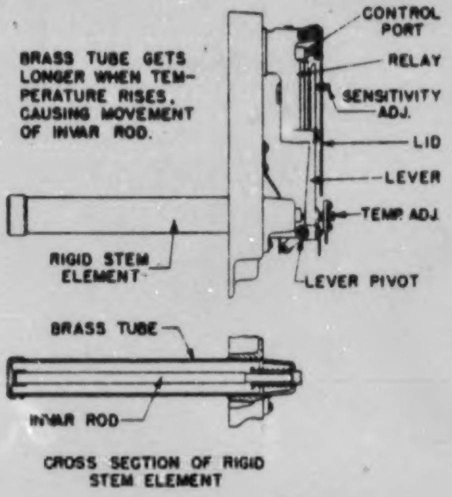

CAPILLARY TUBE
BULB
UNION NUT
DIAPHRAGM
SPRING
MOVEMENT
POST
TEMPERATURE CHANGES CAUSE LIQUID IN BULB TO EXPAND AND CONTRACT. CAPILLARY TUBE TRANSMITS THESE CHANGES TO DIAPHRAGM AND POST.

Figure 25. Remote Bulb-Sensing Element

Rigid Stem (Insertion). This type element uses dissimilar metals in a rod type form. The outer portion being brass with a high coefficient of expansion, and an inner rod of invar. Invar is a metal composed of 36 percent nickel and steel, it has a negligible coefficient of expansion. With an increase in temperature the brass extends moving the invar rod away from the leakport decreasing control air. As the temperature decreases the brass contracts moving the invar rod over the leakport increasing control pressure. See figure 26.


BRASS TUBE GETS LONGER WHEN TEMPERATURE RISES, CAUSING MOVEMENT OF INVAR ROD.
CONTROL PORT
RELAY
SENSITIVITY ADJ.
LID
LEVER
TEMP ADJ
RIGID STEM ELEMENT
LEVER PIVOT
BRASS TUBE
INVAR ROD
CROSS SECTION OF RIGID STEM ELEMENT

FOR CONTROLLING DUCT TEMPERATURES FOR CONTROLLING LIQUID, ELEMENT IS PROVIDED WITH PIPE THREADS.

Figure 26.

Pressure Elements. Pressure elements are used to sense pressure. One type is shown in figure 27. As pressure increases the diaphragm expands covering the leakport, increasing control pressure. As pressure decreases the diaphragm contracts opening the leakport, decreasing control pressure.

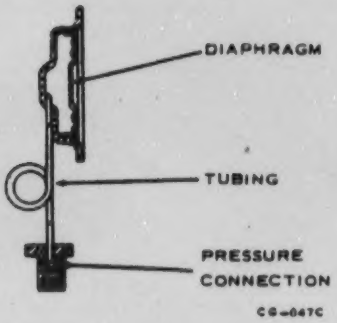

DIAPHRAGM
TUBING
PRESSURE CONNECTION
CG-047C

Figure 27. Pressure Element

Calibration

SENSITIVITY. The sensitivity should always be as high as possible without producing excessive hunting or cycling. The thermostat is factory set for approximately 2 1/2 psi per degree, but the sensitivity is adjustable between 1 and 8 psi per degree. To increase the sensitivity, move the slider toward the control port; to decrease it, move the slider away from the control port. NOTE: DO NOT turn the adjustment screw in the sensitivity slider because the set point of the instrument will shift.

DIAL ADJUSTMENT:

1. Remove capscrew and insert control line test gage into the opening. Apply 15 psi supply air.

2. Note ambient temperature at the bimetal element.

3. Set dial to this temperature.

4. Turn the adjusting screw until the control pressure is in the middle of the spring range of the controlled device.

5. Turn dial to the desired temperature set point, remove the gage, and replace the capscrew.

Note: This instrument has a built-in restrictor which produces a pilot pressure of 5" W.G. No adjustment is necessary.

It must be remembered that these calibration steps are the basic procedures and by no means cover all adjustments necessary. However, these five basic steps will always be included in more complex adjustments. Again, system specifications and the manufacturer's bulletins should be consulted on complex control loops.

ROOM HUMIDISTAT

A room humidistat is a device that senses changes in relative humidity of an individual room. When a change occurs, the humidistat changes the control air pressure to the controlled device. The room humidistat can be used to automatically control the relative humidity for humidification or dehumidification, but only one or the other. It is installed on a wall where it will sense the humidity of the room and modulates the chilled water valve to control the relative humidity (moisture content) of the supply air.

Room Humidistat, H-4100 (see figure 28)

This humidistat is a proportional action, direct or reverse acting instrument designed to control humidifying and dehumidifying equipment. The instrument uses a biwood element and is available either for horizontal or vertical mounting.

SENSITIVITY. The change in control pressure for each unit change in relative humidity, for this instrument is adjustable form 1 to 8 psi per 1 percent relative humidity. The instrument will operate within a range of 10 to 95 percent RH. The dial is marked: WET-MED-DRY, and has a range of 30 percent. Design features of this controller include:

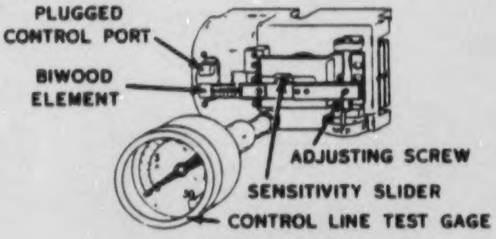


Figure 28. Room Humidistat, H-4100

(1) plug-in mounting, which reduces installation time; (2) built-in resistance to shock and vibration; (3) pneumatic feedback, which provides extremely accurate control even at low sensitivities.

OPERATION. Direct Acting Instrument Operation. On a rising relative humidity the biwood element bends toward the control port. This causes the relay pilot chamber pressure to increase. The increasing pressure actuates the instrument relay, allowing supply air to flow to the control line, thereby increasing the control pressure. Control pressure acting on the feedback diaphragm causes the lever to rotate away from the control port, establishing an exact output pressure corresponding to the humidity measured by the biwood element.

On a decreasing relative humidity the biwood element bends away from the control port, allowing the relay pilot chamber pressure to escape through it to the atmosphere. This decreasing pilot pressure actuates the instrument relay, allowing the control and feedback chamber pressure to simultaneously decrease. The decreasing pressure on the feedback diaphragm causes the lever to rotate toward the control port and output pressure is varied in proportion to the relative humidity change measured by the biwood element.

Reverse Acting Instrument Operation: The operation of a reverse acting instrument is similar to the direct acting humidistat except that the direction that the element bends is reversed. A rising relative humidity causes a decrease in control air pressure and a decreasing relative humidity causes an increase in control air pressure.

The relay used in this controller is the flapper type. A cutaway diaphragm is shown in figure 29.

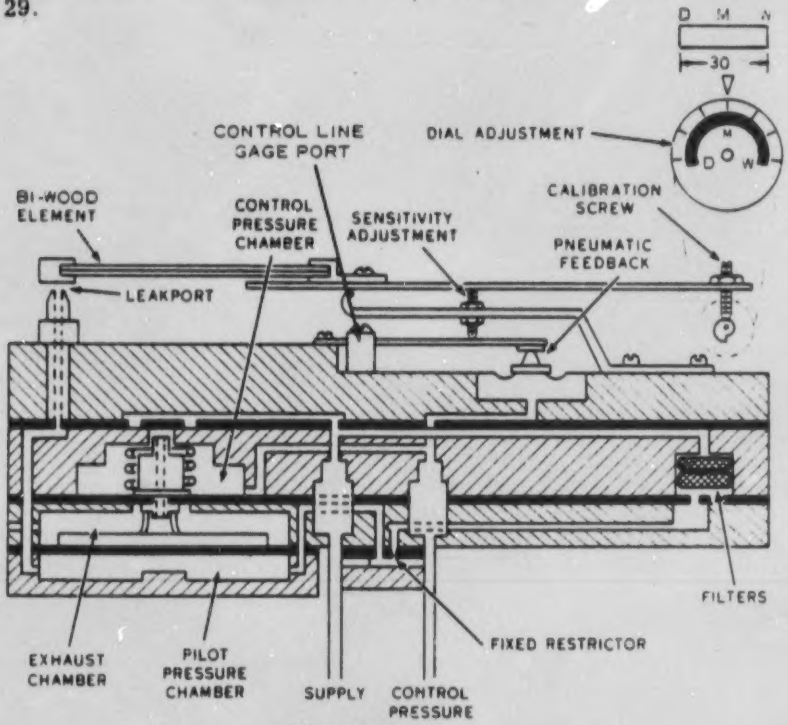
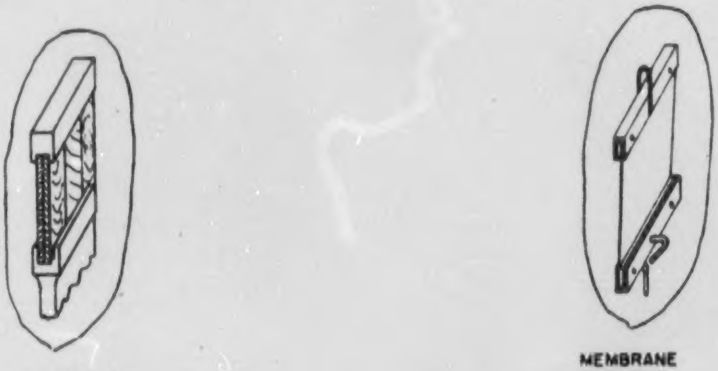

D M W
30
CONTROL LINE GAGE PORT
DIAL ADJUSTMENT
M
D O W
BI-WOOD ELEMENT
CONTROL PRESSURE CHAMBER
SENSITIVITY ADJUSTMENT
CALIBRATION SCREW
PNEUMATIC FEEDBACK
LEAKPORT
FILTERS
FIXED RESTRICTOR
EXHAUST CHAMBER
PILOT PRESSURE CHAMBER
SUPPLY
CONTROL PRESSURE

Figure 29

Humidity Measuring Elements

RELATIVE HUMIDITY. Elements for measuring relative humidity are usually made from hygroscopic materials, which respond to humidity changes by changing their size. These measuring elements are most commonly produced from organic substances such as thin layers of animal horn, wood, membrane, or hair. Animal substances become longer with a rise in relative humidity and shorter with a decrease in humidity, figure 30, and are mounted so that their change in length activates the relay.

Thin strips of two kinds of wood are glued together to form a biwood element, one layer is made of yew wood, cut with the grain running across the width of the strip. The second layer is made from cedar, cut with the grain running the length of the strip. The yew wood cells swell on a rise in humidity and elongate the strip. The cedar strip is less susceptible to moisture changes. This difference in response produces a bending action in the biwood strip, similar to the movement of the bimetal temperature measuring element.



BI-WOOD ELEMENT

BI-WOOD BENDS AS RELATIVE HUMIDITY CHANGES. FOR REVERSE ACTION ELEMENT IS TURNED AROUND.

MEMBRANE ELEMENT

MEMBRANE CHANGES LENGTH AS RELATIVE HUMIDITY CHANGES. FOR REVERSE ACTION POSITIONS OF ELEMENT AND SPRING ARE INTERCHANGED.

Figure 30

The calibration and adjustment of a room humidistat is another important part of your job. Control of humidity in a room is impossible if the humidistat is not properly adjusted. The adjustment and calibration procedures for the humidistat are basically the same as for the room thermostat.

CALIBRATION PROCEDURES. The four basic steps of calibration will again apply. However, the method of determining the ambient relative humidity (RH) will require some special attention.

1. Connect the supply pressure of 20 psig.

2. Determine the ambient relative humidity (RH) and turn the set point dial to correspond with the determined RH: ambient RH may be obtained by using the sling psychrometer and psychrometric chart or a hygrometer.

NOTE: The humidistat has a control range of 10% to 95% RH. The dial range, however is only 30% RH (e.g. 30% to 60% or 20% to 50%) of the control range. The dial can control any 30% between 10% and 95% RH. The dial is marked Dry - Med - Wet so some trial and error adjustments may be necessary.

3. Adjust the calibration screw to bring the control pressure to midrange pressure of the controlled device.

4. Turn set point dial to desired condition: the desired condition should always bring the set point dial to "Med" on the dial. This gives control both above and below set point.

Relative humidity is the ratio of the moisture in the air in comparison to what it could hold at a certain temperature. The ratio is expressed as a percent relative humidity. The humidistat senses the amount of moisture in the air and will raise or lower the moisture content to control the relative humidity.

A sling psychrometer is shown in figure 31. It consists of a frame that has two thermometers attached. One of the thermometers has a cloth sock on its bulb. The sock is dipped in water, and then the psychrometer is slung around the air.

The dry bulb temperature is the measure of the degree Fahrenheit on the thermometer of the sling psychrometer. It measures the intensity of heat.

The air moving past the wetted thermometer causes evaporation, which produces cooling of the thermometer to give a wet bulb reading. This reading is lower than the dry bulb unless the relative humidity is 100%, at which time the wet and dry bulbs will be the same value. If the air is very dry, there will be a rapid and great amount of evaporation and a low wet bulb reading. A high amount of moisture content in the air

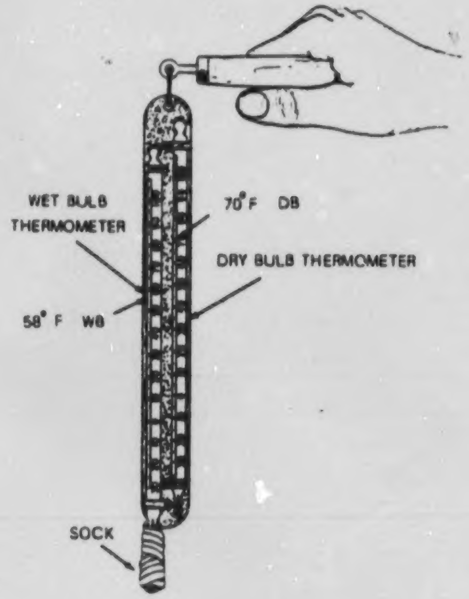


Figure 31. Sling Psychrometer

causes a small amount of evaporation and a greater wet bulb reading. When the air is saturated, there can be no evaporation (cooling); therefore, the wet bulb and dry bulb will be equal.

For example, we will assume a reading on the sling psychrometer of 70°F dry bulb and 58°F wet bulb (see the handout). To find the relative humidity of the air in which the reading was taken, a plot has to be made on the psychrometric chart. The psychrometric chart is a graphic representation of one pound of air and its properties. Looking at a chart, you will see the 70°F dry bulb vertical line intersects the 58° wet bulb line at the 50% relative humidity line. This means that the air is holding one-half or 50% of what it could hold at 70°F.

HEATING-COOLING THERMOSTAT

The heating-cooling thermostat is a controlled device which measures the temperature of an individual room. The heating-cooling thermostat converts temperature changes into pressure changes in the same manner as the room thermostat. The heating-cooling thermostat is a combination of two room thermostats (a direct acting and a reverse acting) into one thermostat. In reality, it is a room thermostat that uses direct acting for control of heating in the winter and reverse acting for control of cooling in the summer. This controller can also be referred to as a summer-winter thermostat.

The heating-cooling thermostat can be used to automatically control the temperature for heating and cooling. The heating-cooling thermostat is installed on a wall where it will sense the temperature of the room. The controller modulates the controlled device to control the flow of chilled water in the summer and hot water in the winter.

The operation of the heating-cooling thermostat is very similar to the operation of the room thermostat, difference being it is applied for both heating and cooling. The application of the heating-cooling thermostat we will discuss is used in conjunction with a two position controller sensing outside conditions and an air switching valve. Before the operation of the heating-cooling thermostat can be appreciated, an understanding of the two position controller and the air switching valve must be gained. We will discuss each one individually and a typical operation for heating and cooling will be shown.

Two-Position Remote Bulb Thermostat

The remote bulb thermostat is for applications which require the sensing element to be located where extreme conditions do not permit controller mounting. The remote bulb controller is equipped with ball type relays which provide more air handling ability and a wider range of control.

OPERATION OF THE TWO-POSITION (POSITIVE) BALL TYPE RELAY, figures 32 and 33. This relay is reverse acting. The main spring normally forces lower diaphragm, exhaust valve seat and upper diaphragm toward the upper diaphragm plate. The exhaust valve spring being stronger than the main valve spring forces the exhaust valve ball against its seat. The main valve spring holds the main valve ball away from its seat. Supply pressure is transmitted to supply air chamber from whence it passes through the main valve to the control air chamber, and then to the final control device. Thus, in its normal position, the two-position relay has full pressure in its control line.

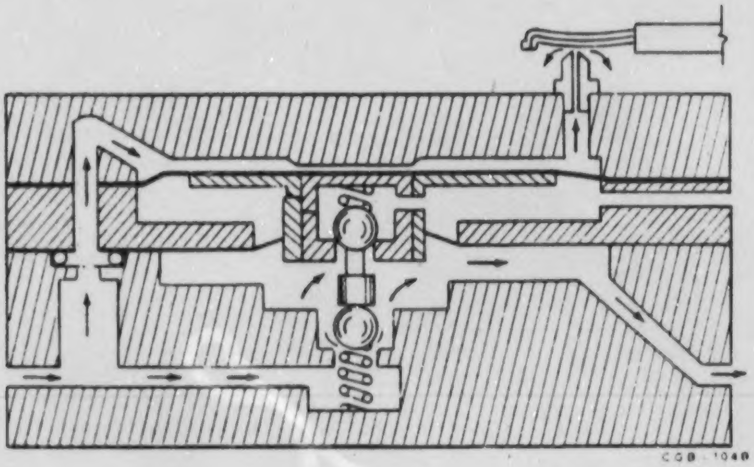


Figure 32. 2-Position Relay Pressurized

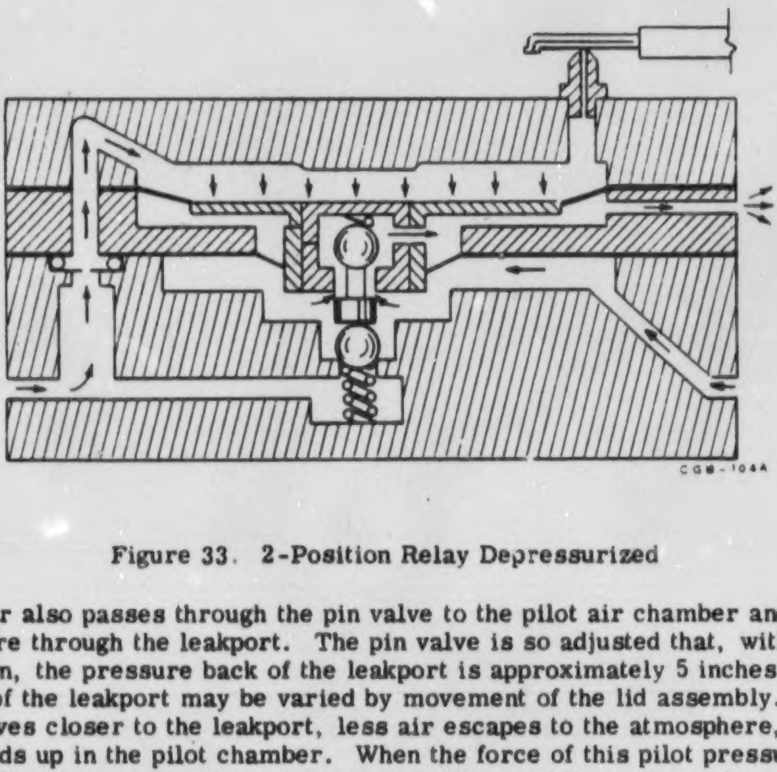


Figure 33. 2-Position Relay Depressurized

Supply air also passes through the pin valve to the pilot air chamber and escapes to the atmosphere through the leakport. The pin valve is so adjusted that, with the leakport wide open, the pressure back of the leakport is approximately 5 inches water gage. The opening of the leakport may be varied by movement of the lid assembly. As the lid assembly moves closer to the leakport, less air escapes to the atmosphere, and the pressure builds up in the pilot chamber. When the force of this pilot pressure acting on the upper diaphragm becomes greater than the force of the main spring plus the force of the full control pressure acting on the lower diaphragm, both diaphragms and exhaust valve seat move in a direction away from the diaphragm plate. This movement is transmitted to the main valve ball by the loose pin and the main valve ball is seated. When the main valve ball is seated, no further movement of this ball takes place, but continued movement of the exhaust valve seat forces the exhaust valve ball off its seat. Air from the control air chamber and control air line escapes to the atmosphere through the exhaust valve. The escape of air from the control air chamber reduces the pressure on the lower diaphragm, thus causing the exhaust valve to open further, assuring that once the control pressure starts to escape, the process will continue until all of the air in the control line is exhausted to the atmosphere.

To again supply pressure to the control line, it is necessary to reduce the pilot pressure by moving the lid assembly away from the leakport. When the force of this pressure on the upper diaphragm becomes less than the force of the main spring, both diaphragms and the exhaust valve are moved toward the upper diaphragm plate by the main spring. The exhaust valve ball closes, then the main valve ball moves away from its seat. Supply pressure flows into the control air chamber and the control air line, and acts against the lower diaphragm to further open the main valve.

The above description shows that once a change in the control pressure has started to take place, the effect of this change on the lower diaphragm is such that the cycle continues until it is completed. Hence, it is impossible for the control pressure to have any value except zero or maximum.

Now that you have a knowledge of ball type relays, we will discuss a controller using this application and the specifications you will need to know for its operation and adjustment.

T-8000 Remote Bulb Thermostat Operation, Figure 34

The instrument is resistant to shock and vibration. The use of flexure levers reduces friction. The thermostat can be made to function as a direct or reverse acting instrument by changing the position of the sliding control port. Sensitivity is also established by positioning the sliding control port. The controller is manufactured as a direct acting instrument, calibrated to produce an output pressure of 8 psi at 70°F with a sensitivity setting of 1 psi per degree F. The output pressure of the thermostat is indicated on an integral 0 to 30 psi gage that is visible through the cover. The set point dial is also visible through the cover. An external dial adjustment is available. The set point dial has ranges on both sides. The range is from -10 to 124 degrees Fahrenheit on one side and from 110 to 244 degrees Fahrenheit on side two. If it is necessary to use the range on the opposite side, place the non-graduated portion of the dial in the same position.

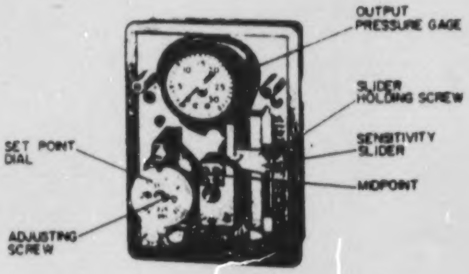


Figure 34. Remote Bulb Thermostat

The control can be made reverse acting by changing the position of the sliding control port, which rides a graduated rail. The rail has graduations which represent approximately 1 psi per degree F, and is marked DA (direct acting) at the top and RA (reverse acting) at the bottom. Moving the slider upward from the midpoint on the rail increases the sensitivity, for direct acting applications, from 0.1 to 5 psi per degree. Moving the slider downward from the midpoint on the rail increases the sensitivity, for reverse acting applications, from 0.1 to 5 psi per degree.

An acceptable reference point for setting sensitivity is 1/3 above or below the mid or pivot point.

Air Switching Valve

The air switching valve, shown in figure 35, is designed to change airflow from one line to another. In dual control systems the valve can be used to switch the supply air from 15 to 19 psi or vice versa. If installed in a heating-cooling application it can direct the control air of a heating or of a cooling thermostat.

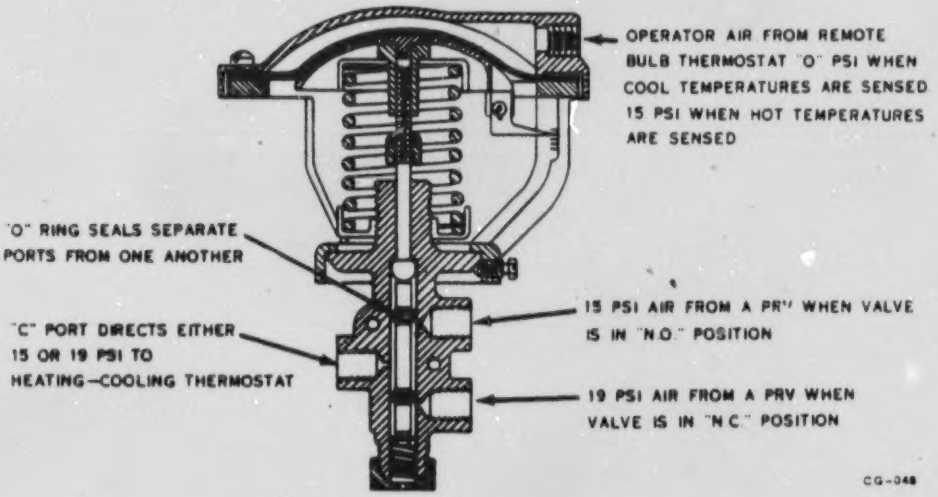

OPERATOR AIR FROM REMOTE BULB THERMOSTAT "O" PSI WHEN COOL TEMPERATURES ARE SENSED 15 PSI WHEN HOT TEMPERATURES ARE SENSED
"O" RING SEALS SEPARATE PORTS FROM ONE ANOTHER
"C" PORT DIRECTS EITHER 15 OR 19 PSI TO HEATING—COOLING THERMOSTAT
15 PSI AIR FROM A PRV WHEN VALVE IS IN "N.O." POSITION
19 PSI AIR FROM A PRV WHEN VALVE IS IN "N.C." POSITION
CG-048

Figure 35. Air Switching Valve

This two-position valve is equipped with a diaphragm operator which has sufficient force to handle all seating pressures. The valve body is constructed of high grade red brass and is considered a three-way valve. All connections into the valve, including the operator are 1/8" female pipe thread. Markings on the valve at the service connections show "C" for common, "N.O." for normally open, and "N.C." for normally closed. The ports are sealed from one another by O-ring seals. With zero pressure applied to the operator the valve is in the normal position.

The operation of the valve is as follows: with zero pressure applied to the operator, air flows through the "N.O." port and out the "C" port to the heating-cooling thermostat. Air flows from a pressure regulating valve set at 15 psi. With 15 psi applied to the operator air flows through the "N.C." port and out the "C" port to the heating-cooling thermostat. Air flows from a second pressure regulating valve set at 19 psi.

CALIBRATION. The air switching valve requires no calibration. Because of the difficulty of simulating conditions, no calibration of the T-8000 remote bulb thermostat will be attempted in the classroom, a discussion of the procedures will be outlined in the classroom.

Heating application of the complete system using the T-8000 two-position, remote bulb thermostat, air switching valve, and the T-4752 heating-cooling thermostat is shown in figure 36. Looking at figure 36 you see that zero psi comes to the air switching valve when the outdoor thermostat senses a cool temperature. The "N.O." and "C" ports of the air switching valve are open directing 15 psi to the heating-cooling thermostat. Looking at figure 37 you see that the thermostat has two bimetallic sensing elements, the 15 psi supply air goes through the switchover mechanism and supplies pressure to the upper pilot chamber and out the corresponding leak-port. The lower sensing element being direct acting bends down on a rise in temperature which gives a rise in control pressure. The rise in control air pressure from the controller modulates the controlled device to regulate the amount of hot water for heating the air.

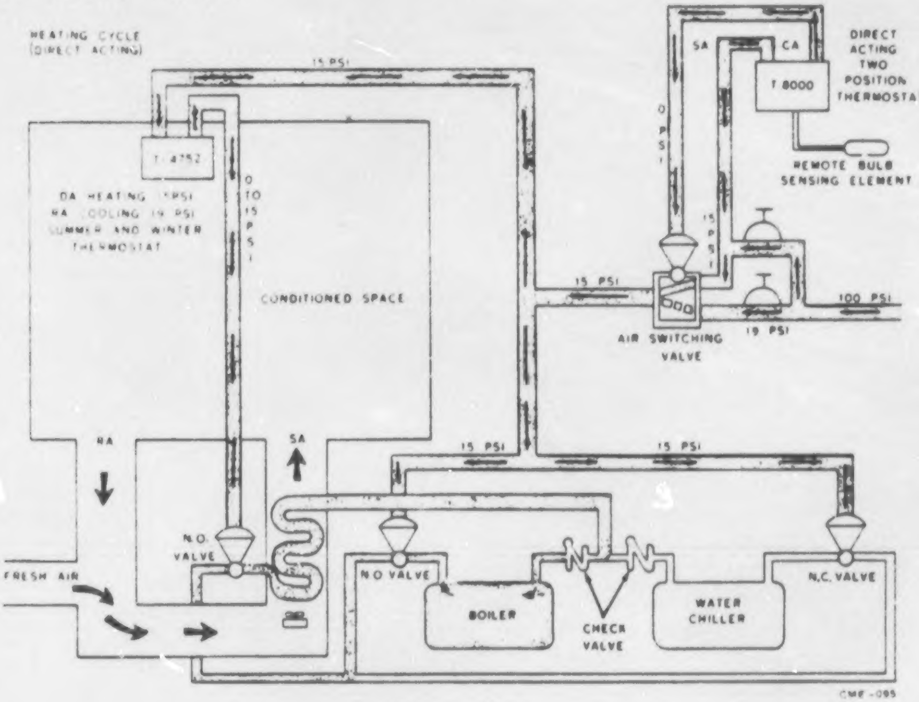
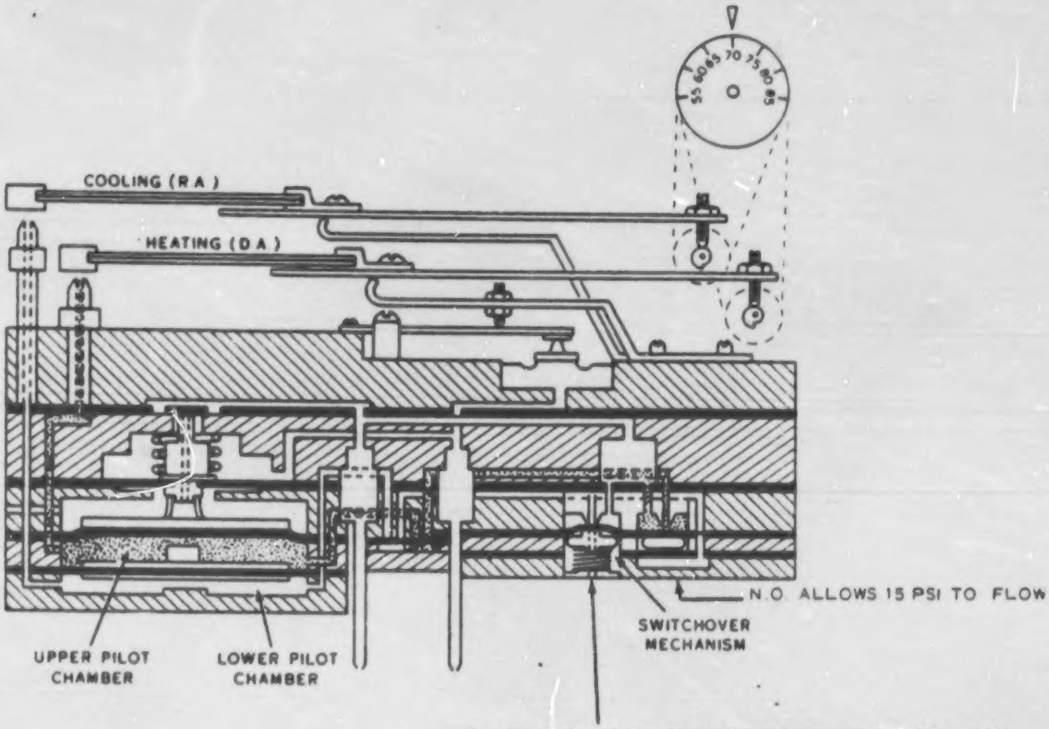

HEATING CYCLE
(DIRECT ACTING)
15 PSI
T-4752
DA HEATING 15 PSI
RA COOLING 19 PSI
SUMMER AND WINTER
THERMOSTAT
0 TO 15 PSI
CONDITIONED SPACE
SA
CA
T 8000
DIRECT
ACTING
TWO
POSITION
THERMOSTAT
0 PSI
REMOTE BULB
SENSING ELEMENT
15 PSI
15 PSI
100 PSI
19 PSI
AIR SWITCHING
VALVE
RA
SA
15 PSI
15 PSI
N.O.
VALVE
FRESH AIR
N.O VALVE
BOILER
CHECK
VALVE
WATER
CHILLER
N.C. VALVE
CMF-095

Figure36



N.C. IT TAKES 19 PSI OR MORE TO DEPRESS DIAPHRAGM
A SMALL PORTION FLOWS THROUGH A DRILLED PASSAGE
AND CLOSES N.O. CHAMBER ALLOWING 19 PSI TO FLOW
TO LOWER PILOT CHAMBER

Figure 37

Cooling application of the complete system using the T-8000 two-position, remote bulb thermostat, air switching valve, and the T-4752 heating-cooling thermostat is shown in figure 38. Looking at figure 38 you see that 15 psi comes to the air switching valve operator when the outdoor thermostat senses a hot temperature. The "N.C." and "C" ports of the air switching valve are open directing 19 psi to the heating-cooling thermostat. Looking at figure 39 you see that the rise in supply pressure causes the switchover mechanism to send pilot pressure to the lower chamber. The upper sensing element being reverse acting bends upward and lowers the pilot pressure on a rise in temperature. The decrease in pilot pressure allows the exhaust port to open and exhaust a portion of the control air from the control line through the controller. The decreased control pressure from the controller modulates the controlled device to regulate the amount of chilled water for cooling the air.

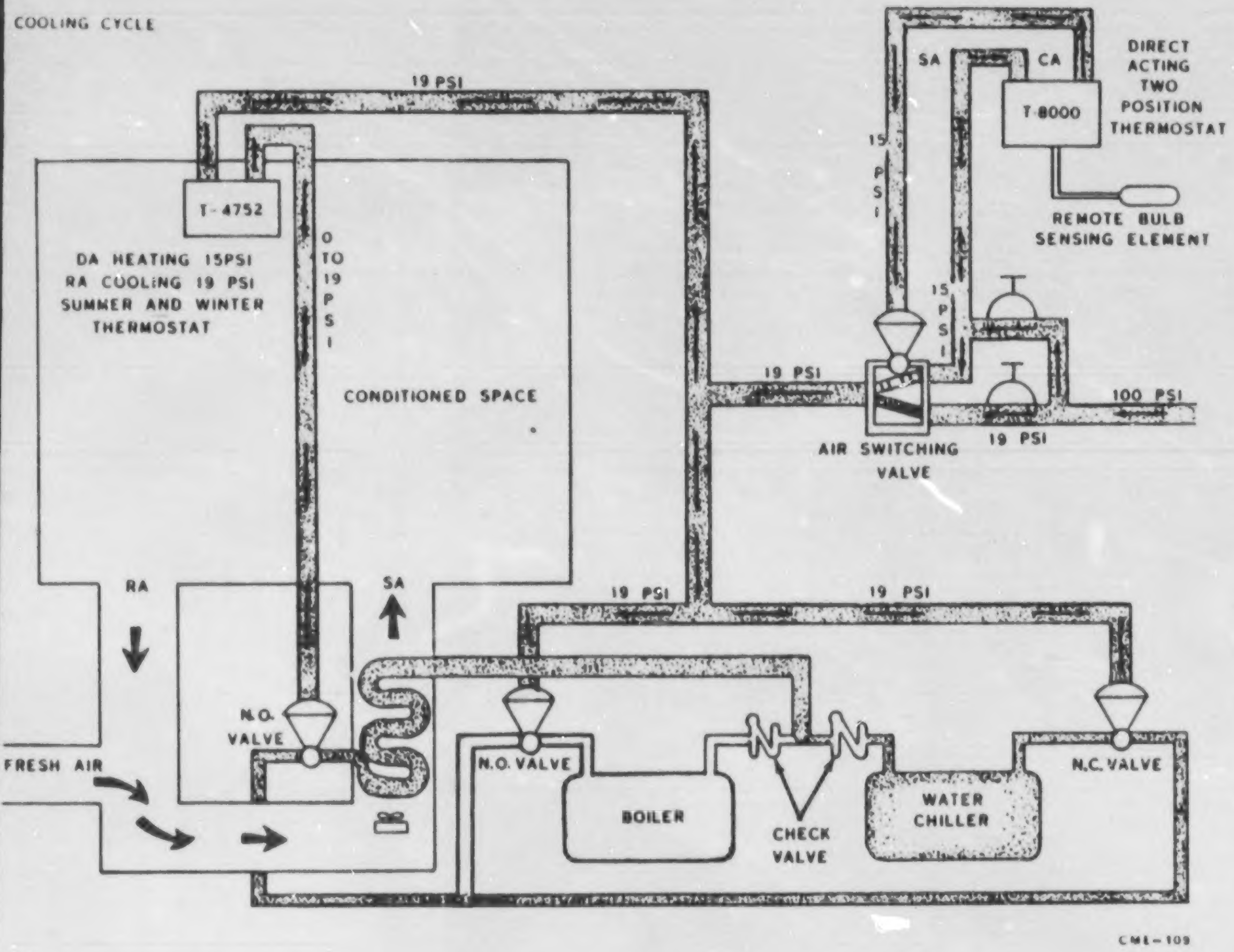

COOLING CYCLE
19 PSI
T-4752
DA HEATING 15PSI
RA COOLING 19 PSI
SUMMER AND WINTER
THERMOSTAT
0 TO 19 PSI
CONDITIONED SPACE
RA
SA
N.O. VALVE
FRESH AIR
SA
CA
T-8000
DIRECT ACTING TWO POSITION THERMOSTAT
15 PSI
REMOTE BULB SENSING ELEMENT
15 PSI
19 PSI
100 PSI
AIR SWITCHING VALVE
19 PSI
19 PSI
19 PSI
N.O. VALVE
BOILER
CHECK VALVE
WATER CHILLER
N.C. VALVE
CML-109

Figure 38.

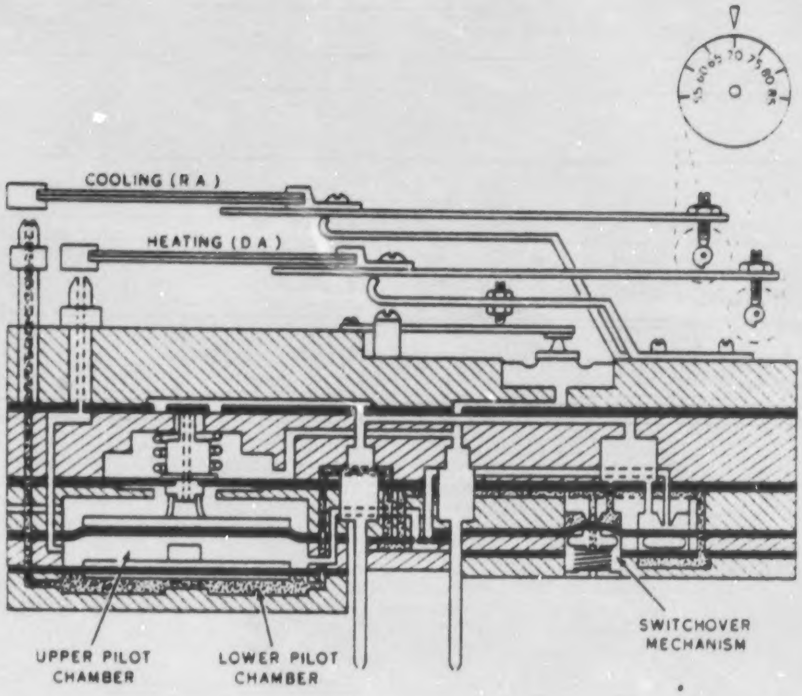


Figure 39

The calibration and adjustment of a heating-cooling thermostat is another important part of your job. Control of the temperature in a room in summer and winter is impossible if the thermostat is not properly adjusted.

CALIBRATION PROCEDURES. In the heating and cooling thermostat it must be remembered that two (2) calibrations are necessary, one for each sensing element. Since the steps are identical, we will list only one procedure. We will assume that both set point temperatures are the same for calibrating.

1. Adjust supply pressure to 15 psig; this is accomplished by using the pressure regulating valve (PRV).

2. Determine ambient temperature and turn set point dial to this temperature; use a thermometer to obtain ambient temperature.

3. Adjust the lower calibration screw to bring the control pressure to midspring range of the controlled device.

4. Adjust supply pressure to 19 psig; again by adjusting the PRV.

5. Repeat steps 2 and 3 used with 15 psig supply pressure with one exception: use the upper calibration screw to adjust control pressure.

RP908A CONTROLLER WITH LP914A SENSOR

LP914A Sensor (Figure 40)

There are four types of sensors, temperature, humidity, pressure, and dewpoint. Each can be used with the RP908A nonbleed controller. The temperature sensor, which we will work with, has an invar rod, brass rod, and a stainless steel lid.

The sensor can be inserted into a duct or large water pipe in a remote area. It is connected to the controller by tubing.

OPERATION. On an increase in temperature the brass rod expands, moving the invar rod away from the lid. With the lid closed, the pressure will back up to the input chamber of the controller.

On a decrease in temperature the brass rod will contract, causing the invar rod to move the lid away from the seat. The movement of the lid is less than one ten-thousandths (.0001) of an inch. This will allow all pressure above 3 psi to escape to the atmosphere.

The sensor will operate accurately at a distance of one mile or less, and it is not affected by vibration.

CALIBRATION. The sensor is factory calibrated and sealed with a plastic cover. If the sensor fails, the complete sensor should be removed and replaced. DO NOT ATTEMPT TO CALIBRATE.

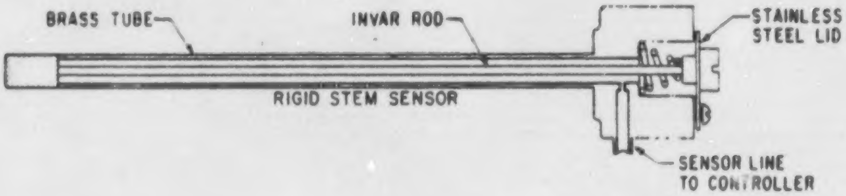


Figure 40. LP914A Sensor

RP908A Controller

The controller can be located in a remote equipment room or on a control panel. It is connected to the sensor by tubing and takes a small pressure change from the sensor and amplifies it through the main lever, secondary lever, and the relay chamber to provide a 3 to 15 psig branch line pressure.

The controller is equipped with three springs (see figure 41). The two small springs are connected to the secondary lever if reverse action is desired or disconnected if direct action is desired. The large spring is used only when the proportional band adjustment is set at 15% or above.

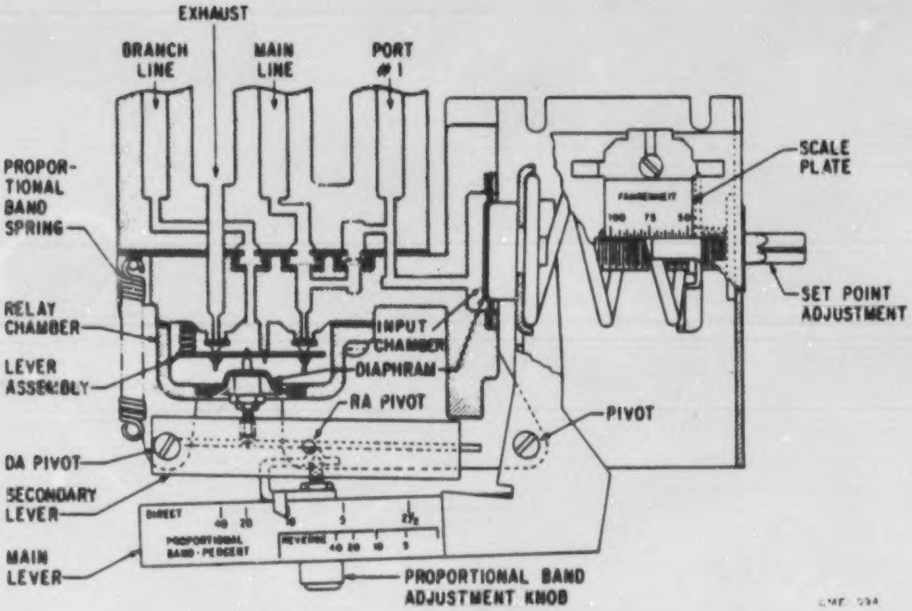

EXHAUST
BRANCH LINE
MAIN LINE
PORT #1
PROPORTIONAL BAND SPRING
SCALE PLATE
FAHRENHEIT
100
75
50
SET POINT ADJUSTMENT
RELAY CHAMBER
INPUT CHAMBER
LEVER ASSEMBLY
DIAPHRAM
RA PIVOT
PIVOT
DA PIVOT
SECONDARY LEVER
DIRECT
40
20
10
5
2½
PROPORTIONAL BAND-PERCENT
REVERSE
40
20
10
5
MAIN LEVER
PROPORTIONAL BAND ADJUSTMENT KNOB

Figure 41. RP908A Controller

OPERATION. The main air enters the controller where it passes through a small restrictor (.005), to port #1 (which is connected to the sensor) and the input chamber. On a rise in temperature the pressure will increase in the input chamber moving the main lever against the set point adjustment spring. This movement causes the main lever to push up on the secondary lever, which will pivot the secondary lever upwards. This causes the lever assembly to pivot on the exhaust port, which causes the main air port to open allowing air pressure to enter the relay chamber, thus supplying air to the branch line and operating the controlled device.

On a decrease in temperature the sensor will bleed the pressure from the input chamber, causing all the levers to move in the opposite direction, and the lever assembly will pivot on the main air port to allow the branch line pressure to bleed out the exhaust port.

SUMMARY

Air-conditioning systems are fast becoming an automatic factory in which the product is the production of conditioned air. Controls dominate the process; therefore it is necessary that you understand the theory of controls, bleed, two-position, and proportional. A knowledge of the terms applied to controls and the applications are essential, so these controls operate at peak efficiency.

A pneumatic valve controls the flow of water and steam, a pneumatic damper operator controls various arrangements of dampers to control airflow.

The pilot positioner is used on valves and damper operators to make them more positive and sensitive to small changes in control pressure.

A room thermostat is a device that measures the temperature of an individual room. The thermostat converts the temperature changes into an air pressure (control pressure) that is sent to a controlled device (valve or damper). The controlled device regulates the flow of the control agent (chilled water, hot water, steam, etc) which will control the temperature.

A room humidistat is a device that senses changes in relative humidity of an individual room. When a change occurs, the humidistat changes the control air pressure to the controlled device.

The heating-cooling thermostat is equipped with two bimetallic elements. The standard model operates as a direct acting thermostat for heating and as a reverse acting thermostat for cooling. The changeover from heating to cooling is accomplished by changing the supply pressure. The change in supply air pressure actuates an indexing bellows which positions a set of cams, making one strip inoperative while the other is free to operate. Each of the two bimetal thermostatic elements has its own calibrating mechanism and can be adjusted to meet the condition of the installation.

The temperature sensor is connected by tubing to the controller. The action of the controller can be changed by moving the pivot point and connecting the reverse action springs. A larger spring is connected to the main lever when the proportional band setting is above 15%.

QUESTIONS

1. What are three applications of pneumatic controllers?

2. What determines the pressure in the air supply tank?

3. What determines the pressure in the supply line?

4. What determines the pressure of the control air?

5. What are the parts of the control loop?

6. Where does the air first enter the system?

7. Which side of the controller does the air enter?

8. What is the usual pressure of supply air?

9. What is the range of control air for proportional controllers? ______________________

10. What are three control agents? ______________________

11. What is a characteristic of a two-position control loop: ______________________

12. What is the purpose of any sensing element? ______________________

13. What is desired temperature referred to as? ______________________

14. What is the difference between set point and control point? ______________________

15. What is throttling range? ______________________

16. What is the designation of a controller that decreases control pressure on a drop in measurable variable?

____

17. What is the designation of a controller that decreases control pressure on a rise in measurable variable?

18. What is sensitivity?

19. In operation, what are two types of pneumatic valve?

20. What is required to actuate a normally open pneumatic valve?

21. How can the actual spring range of a pneumatic valve be determined?

22. What is the midrange pressure for a pneumatic valve that begins opening at 5 psi and is fully opened at 12 psi?

23. Can the pneumatic valve be used to control the flow of air?

24. What is a mixing or bypass valve?

25. If a damper operator has a range of 2-14 psi: What would you regulate pressure to?

____

____

26. What limits the travel of the damper operator? ____________________

____

____

27. Where should the stops on the damper operator be adjusted to? ____________

____

____

28. What are two adjustments on the damper operator? ________________

____

____

29. What is the source of air to the pilot chamber? ____________________

____

____

30. What is the name of the four chambers of the pilot positioner? ____________

____

____

31. How is the operating range changed on the pilot positioner? ____________

____

____

32. What can you add to a pneumatic actuator to make it more positive and more sensitive to small changes in control pressure?

____

____

33. What are two adjustments that can be made on the pilot positioner?

34. What are the names of the five air chambers in the relay used with the T-4002 and H-4100?

35. What would occur if you lost control air from a controller?

36. What is the purpose of the pneumatic relay in a pilot-bleed type controller?

37. On bleed-type instruments: What opens or closes the leakport to allow supply air to enter the control chamber?

38. When is a proportional controller in a balanced position?

39. What is pneumatic feedback?

40. What type sensing element is found on the T-4002?

41. What part of a pneumatic controller do you adjust to regulate the control pressure?

42. What type of sensing element is found on the H-4100 humidistat?

43. When calibrating a humidistat: Where is the indicator dial set?

44. What is the dial range of most humidistats?

45. Why calibrate the controller to midrange of the controlled device?

46. If you have an RA humidistat on an NC steam valve: What will the valve do on an increase in relative humidity?

47. What is the sensitivity of a humidistat defined as?

48. What action is used in the summer-winter thermostat?

49. In order to calibrate a summer-winter thermostat correctly: Where do you position the dial?

50. Does the heating-cooling thermostat automatically maintain a constant temperature during summer and winter?

51. What air pressure is supplied to the system when the air switching valve is in the normal position?

52. In a pneumatic control system designed for heating and cooling: How is the supply air to the heating-cooling thermostat increased and decreased?

53. What is the dial range of the T-8000 remote bulb thermostat?

54. What is the range of the sensitivity of the remote bulb thermostat?

55. How can the action of the RP-908A controller be changed from RA to DA?

56. What is the definition for Proportional Band?

57. When does the controller use main air?

58. What is the temperature range of the LP914A sensor?

59. With a scale plate of 50°F to 150°F, what would the scale range be?

60. What are the different types of sensors that can be used with the RP908A controller?

61. What are the advantages of the RP908A controller?

62. When must the proportional band spring be connected?

REFERENCES

1. Johnson Service Company Apparatus and Service Bulletins
2. Minneapolis-Honeywell Company Service Bulletins
3. Instruments and Process Control, New York Vocational and Practical Arts Publication

WORKBOOKS 3ABR54530-VII-1-P1 and P2
and 2-P1 thru P7

Department of Civil Engineering Training

Refrigeration and Air-Conditioning Specialist

AIR COMPRESSING EQUIPMENT
AND PNEUMATIC CONTROLS

July 1975

SHEPPARD AIR FORCE BASE

11-8

Designed For ATC Course Use

DO NOT USE ON THE JOB

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WB 3ABR54530-VII-1-P1
July 1975

IDENTIFYING COMPONENTS OF AN AIR COMPRESSOR SYSTEM

OBJECTIVE

To be able to locate and identify the major components of an air compressing system.

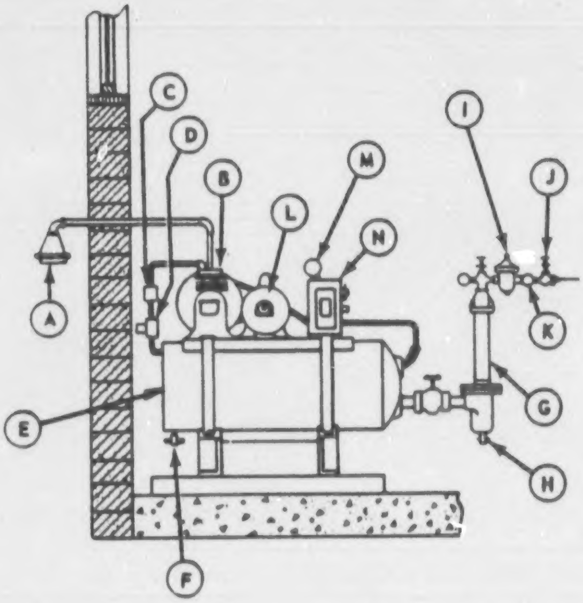

Figure 1. Air Compressing System

270

1. Identify each of the lettered items on figure 1 by placing their name and purpose in the following form beside the item letter.

ITEM	NAME	PURPOSE
A		
B		
C		
D		
E		
F		
G		
H		
I		
J		
K		
L		
M		
N		

OPERATOR MAINTENANCE OF AN AIR COMPRESSOR SYSTEM

OBJECTIVE

To be able to service and perform maintenance on an air compressor system.

NOTE: This performance will be accomplished on a system designated by the instructor.

1. Turn all electrical switches to the OFF position.

2. Visibly check condition of electrical wires.

3. Are the wires in good condition? ______________

   If "NO," inform the instructor.

4. Check oil.

   a. Is the oil level correct? ______________________________

   b. What is the condition of the oil? __________________________

5. Check the air intake filter: Is it clean enough for proper operation? ________

6. Check the compressor belts:

   a. What is the actual belt depression? __________________________

   b. Correct tension allows approximately ____________ inch of belt depression

7. Drain all water from tank by opening the hand drain valve.

8. Turn compressor line starter ON.

9. After compressor cycles OFF:

   a. What is the high pressure supply? ____________________ psig

   b. Check the pressure reducing valve (PRV) setting.

      What is the supply pressure? ____________________ psig.

Checked by ______________________________
Instructor

IDENTIFICATION AND DEFINITION OF CONTROL COMPONENTS AND TERMS OF A PNEUMATIC CONTROL SYSTEM

OBJECTIVE

To locate and define pneumatic control system components and terms.

LOCATING AND DEFINING CONTROL TERMS

1. Study the control loop shown in figure 2.
2. From this loop list the number that corresponds to the control term listed and then give its definition.

a. Set Point, No. ____________ Definition ____________________________
____

b. Desired Value, No. ________ Definition ____________________________
____

c. Control Point, No. __________ Definition ____________________________
____

d. Direct Acting Controller, No. ________ Definition __________________
____

e. Normally Closed Valve, No. __________ Definition __________________
____

f. Control Agent, No. __________ Definition ____________________________
____

g. Control Line, No. __________ Definition ____________________________
____

h. Supply Line, No. ___________ Definition ______________________________
____

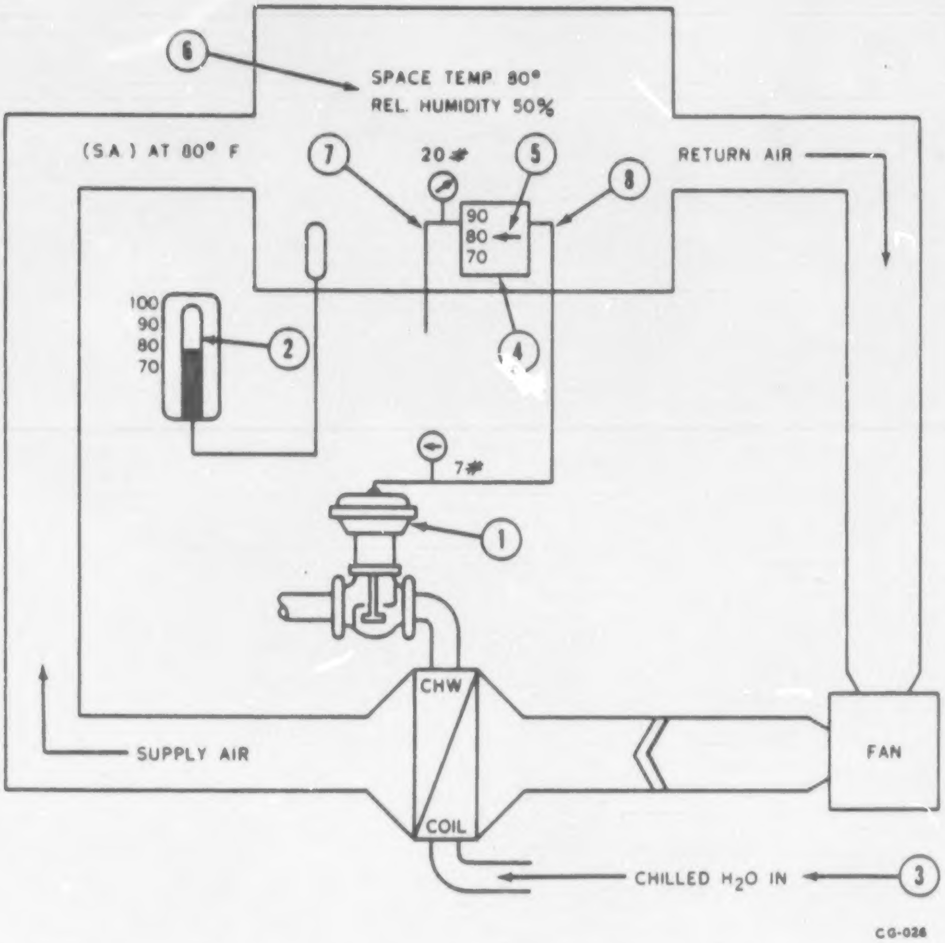
⑥
SPACE TEMP 80°
REL. HUMIDITY 50%
(S.A.) AT 80° F
⑦
20#
⑤
⑧
RETURN AIR
90
80
70
100
90
80
70
②
④
7#
①
CHW
COIL
FAN
SUPPLY AIR
CHILLED H_2O IN
③
CG-026

Figure 2. Control Loop

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DETERMINING THE MIDSPRING RANGE OF A PNEUMATIC VALVE

OBJECTIVE

To determine the midspring range of a pneumatic valve.

1. Locate trainer assigned by instructor.
2. Preoperational checks.
   a. Close all air line valves
   b. Check Master Switch for ON position
   c. Check air compressor switch for ON position.
3. Connect the valve to the variable supply pressure. See figure 3.
4. Operational safety checks.
   a. Check for air leaks.
   b. At no time during operation should the controlled devices be handled.
5. Increase the pressure until valve moves.

   At what pressure did it move? ________________ psig
6. Raise the pressure until the valve stops moving.

   At what pressure did it stop? _________________ psig
7. Figure the difference of the two pressures.
   a. Start __________________ psig.
   b. Stop __________________ psig.
   c. Midrange ______________ psig.

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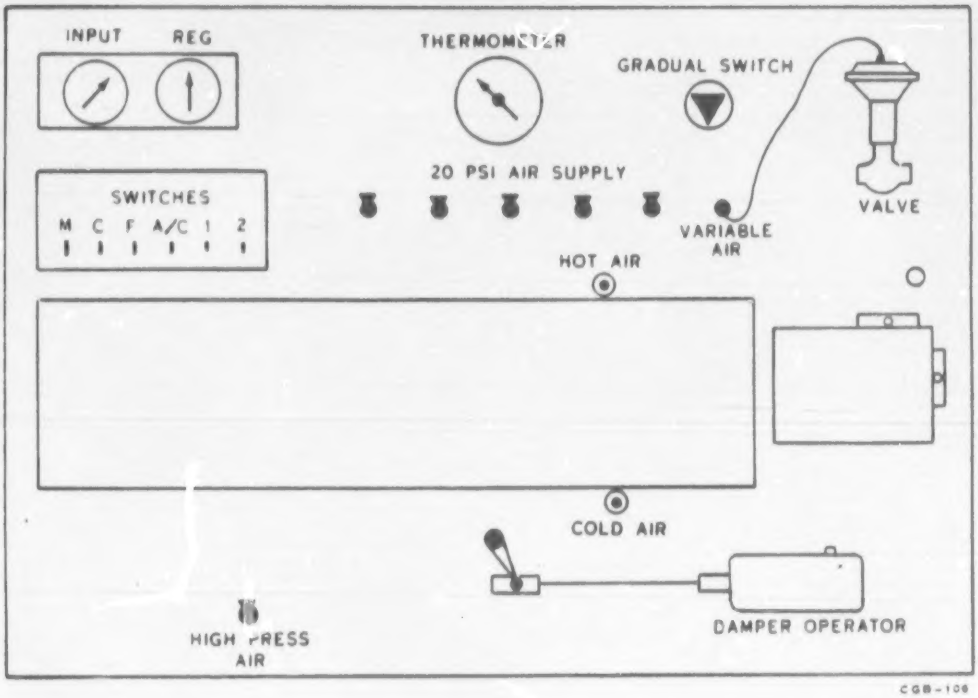
INPUT
REG
THERMOMETER
GRADUAL SWITCH
VALVE
SWITCHES
M C F A/C 1 2
20 PSI AIR SUPPLY
VARIABLE AIR
HOT AIR
COLD AIR
HIGH PRESS AIR
DAMPER OPERATOR
CGB-106

Figure 3.

8. Have the instructor check your work.

9. Shutdown procedures.

   a. Close air line valves.

   b. Disassemble hoses from regulators and valve.

   c. Check all switches for OFF position.

10. Have instructor check your work.

Checked by ______________________________
Instructor

ADJUSTMENTS OF A PNEUMATIC DAMPER OPERATOR

OBJECTIVE

To adjust a pneumatic damper operator.

PROCEDURES

Accomplish all preoperational checks listed below prior to operation of the trainer and observe the listed procedures closely during all operations.

PREOPERATIONAL CHECKS AND ADJUSTMENTS

1. Locate trainer assigned by instructor.
2. Preoperational checks.
   a. Close all air line valves.
   b. Check Master Switch for ON position.
   c. Check Air Compressor Switch for ON position.
3. Connect damper operator as shown in figure 4.
4. Increase the pressure from the gradual switch until the operator stem just begins to move. At what pressure did this occur? ______________ psi
5. Increase the pressure from the gradual switch until the stem fully extends. At what pressure did this occur? ______________ psi.
6. What is the midrange of this operator? ______________ psi.
7. What is the desired stroke of the operator? ______________ inches.
   What is the actual stroke of the operator? ______________ inches.
   Reduce pressure to zero.

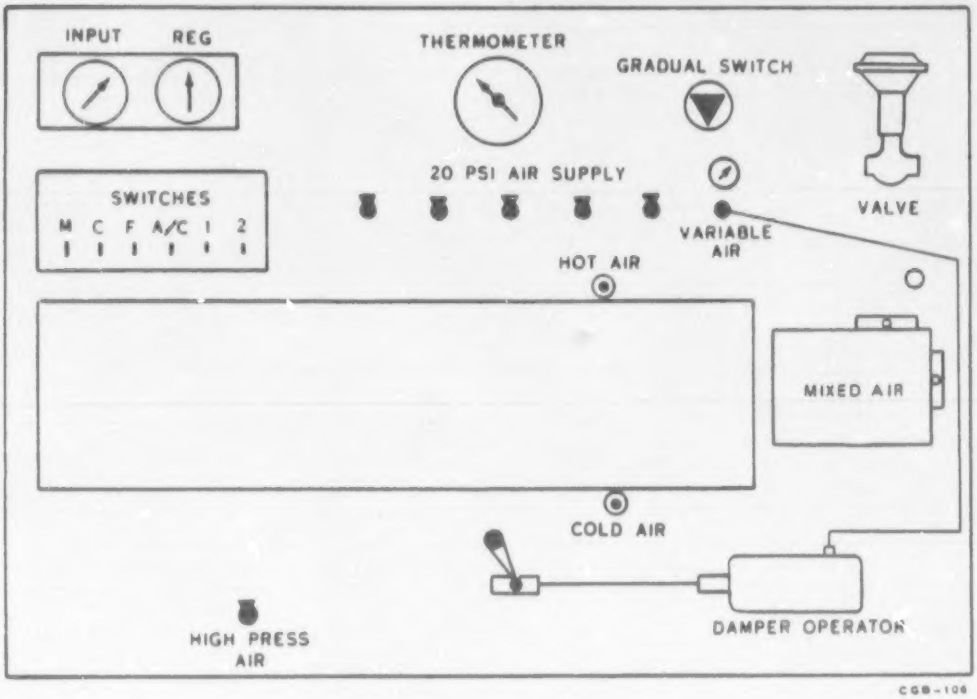
INPUT
REG
THERMOMETER
GRADUAL SWITCH
VALVE
20 PSI AIR SUPPLY
SWITCHES
M C F A/C 1 2
VARIABLE AIR
HOT AIR
MIXED AIR
COLD AIR
DAMPER OPERATOR
HIGH PRESS AIR
CGB-106

Figure 4.

8. The normal position of a damper assembly is determined by ____________________

____

ADJUSTING OPERATOR STOPS

1. Check the retracted stroke by completing the following steps:
   a. Apply air pressure to move operator stem slightly.
   b. Loosen locknut and back off completely.
   c. Release air pressure.
   d. Tighten stop nut against housing.
   e. Add air pressure enough to move the stem approximately 1/8 inch; then tighten stop nut against housing again. (This step allows clearance between diaphragm and cylinder head to keep from hammering the diaphragm between head and piston.)
   f. Tighten locknut against stop nut.

2. Check extended stroke by completing the following steps:
   a. Apply pressure which is equal to the top of the spring range of the operator.
   b. Loosen locknuts on the two stop screws at front of operator.
   c. Adjust stop screws evenly until they contact the piston.
   d. Tighten locknuts.
3. Have instructor check your work.
4. Shutdown procedures.
   a. Close all line valves.
   b. Disassemble hoses from regulators and damper operator.
   c. Check all switches for OFF position.
5. Have instructor check your work.

Checked by ______________________
Instructor

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OPERATION AND ADJUSTMENT OF PILOT POSITIONER

OBJECTIVE

To adjust a pilot positioner.

PROCEDURES

Accomplish all preoperational checks listed below prior to operation of the trainer and observe the listed procedures closely during all operations.

ADJUSTMENT OF PILOT POSITIONER ON DAMPER OPERATOR

1. Locate trainer assigned by instructor.
2. Perform preoperational checks as follows:
   - a. Close all air line valves.
   - b. Check Master Switch for ON position
   - c. Check Air Compressor Switch for ON position.
3. Connect the positioner as shown in figure 5.

NOTE: Make sure pilot spring is connected to pilot positioner lever arm.

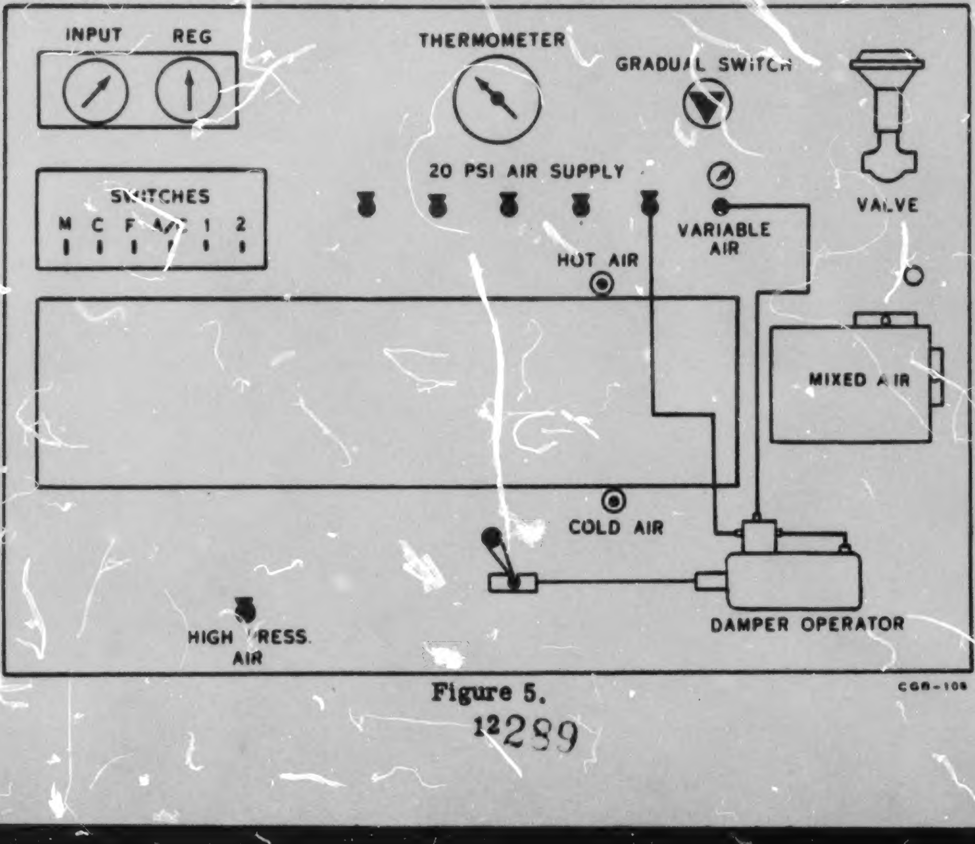
INPUT
REG
THERMOMETER
GRADUAL SWITCH
VALVE
20 PSI AIR SUPPLY
SWITCHES
M C F A/C 1 2
VARIABLE AIR
HOT AIR
MIXED AIR
COLD AIR
DAMPER OPERATOR
HIGH PRESS. AIR
CGR-109

Figure 5.

4. Apply supply pressure (20 psi) to the pilot positioner.

5. Increase the pressure (pilot) from the gradual switch until operator begins to move.

   a. At what pilot pressure did the stem begin to move? ____________________ psi

   b. Can this starting pressure be changed? ________________________________

6. Increase the pilot pressure until piston touches the stops. At what pressure did the operator stop? ____________________ psi.

7. What operating range did the pilot positioner produce? ________________________

ADJUSTMENT

1. Operating range is determined by the ______________ and ________________________ ____________________ adjustments of the pilot positioner.

2. Operating span is adjustable from ______________ psi to ________________ psi.

3. Starting point is:

   a. Adjustable from ____________________ psi to ____________________ psi.

   b. Established by adjusting the screw located under the cover. Turning screw counterclockwise ________________________________ starting point. Turning the screw clockwise ________________________ starting point.

4. Adjustment. The operator installed on the trainer has a spring range of 8 to 13 psi (5 psi span) and it is desired to use the pilot positioner to obtain an operating range of 8 to 13 psi. The starting point will be 8 psi, and a span of 5 psi.

   a. Place one end of the pilot spring in the hole of the lever arm that will give a 5 psi span.

   b. Increase pressure from the gradual switch to 8 psi.

   c. Turn adjusting screw until the operator just begins to move.

   d. The pilot positioner will now position the piston damper operator over a range of 8 to 13 psi.

   e. Vary pilot pressure from gradual switch to check for proper starting and span.

5. Have instructor check your work.

6. Shutdown procedures.

   a. Close all line valves.

   b. Disassemble hoses from regulators and controls.

   c. Check all switches for OFF position.

7. Have instructor check your work.

Checked by ______________________
Instructor

CALIBRATING A PNEUMATIC ROOM THERMOSTAT

OBJECTIVE

To calibrate a room thermostat.

PROCEDURE

Accomplish all preoperational checks listed below prior to operation of the trainer and observe the listed procedures closely during all operations.

PREOPERATIONAL CHECKS AND ADJUSTMENTS

1. Locate trainer assigned by instructor.
2. Preoperational checks and control settings.
   a. Close all air line valves.
   b. Check Master Switch for ON position.
   c. Check Air Compressor Switch for ON position.
3. Using a T-4002 Room-type thermostat and damper operator connect temperature control loop as shown in figure 6.
4. Apply 20 psi to thermostat.
5. Is the thermostat direct or reverse acting? ______________________
6. Check the sensitivity setting of the instrument. The sensitivity adjustment should always be as high as possible without producing excessive hunting or cycling. To increase the sensitivity, move slider toward control port. To decrease the sensitivity, move the slider away from the control port. Make necessary slider adjustment.
7. Adjust slider.
   a. Turn set-point dial to produce an intermediate pressure on the control air pressure gage (say 10 psi).
   b. Move slider to desired sensitivity setting.
   c. Turn adjusting screw in the sensitivity slider until the pressure on the control pressure gage returns to the same pressure as indicated in step 7a.

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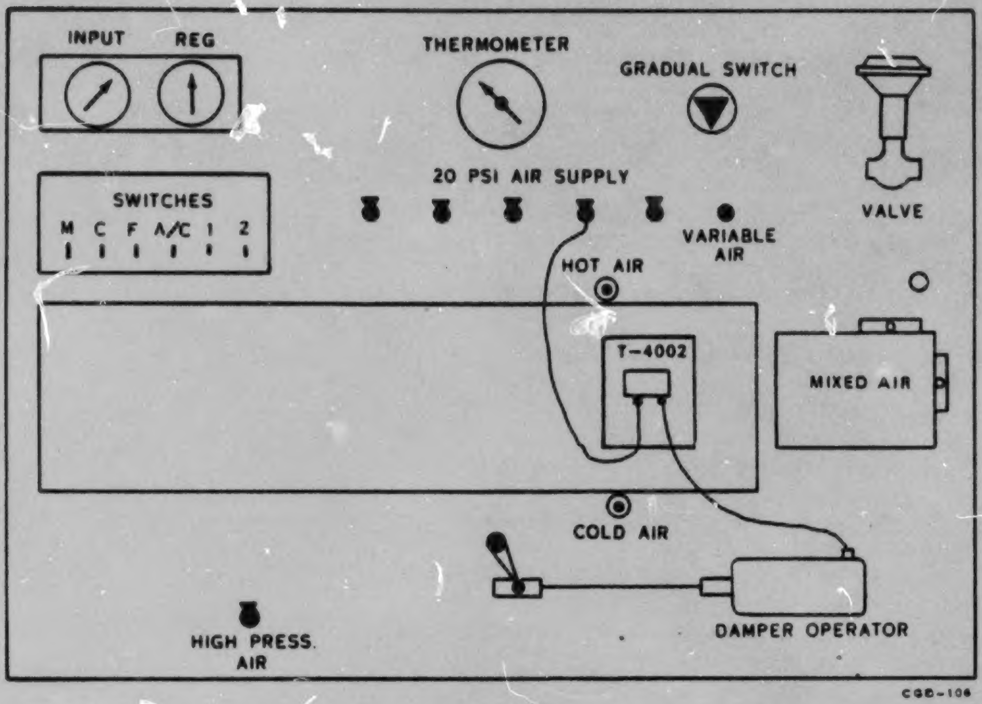
INPUT
REG
THERMOMETER
GRADUAL SWITCH
VALVE
SWITCHES
M C F A/C 1 2
20 PSI AIR SUPPLY
VARIABLE AIR
HOT AIR
T-4002
MIXED AIR
COLD AIR
DAMPER OPERATOR
HIGH PRESS. AIR
CGD-106

Figure 6. Single Temperature Thermostat Application

DIAL ADJUSTMENT

1. Note ambient temperature at the bimetal element with fan, heaters, and air conditioner off.

2. Set dial to correspond to temperature prevailing at the bimetal element.

3. Turn adjusting screw, above set point dial, until control air pressure reading on the gage is at midrange.

4. Turn dial to desired temperature set point (75°F).

5. Turn on fan, heaters and air conditioner. Observe response of controller.

6. Shutdown procedures.

    a. Close air line valves

    b. Disassemble hoses from regulators and controls

    c. Check all switches for OFF position

7. Replace cover.
8. Have instructor check your work.

Checked by ______________________________
Instructor

CALIBRATING A PNEUMATIC HEATING-COOLING THERMOSTAT

OBJECTIVE

To calibrate a heating-cooling thermostat.

PROCEDURES

Accomplish all preoperational checks listed below prior to operation of the trainer and observe the listed procedures closely during all operations.

PREOPERATIONAL CHECKS AND ADJUSTMENTS

1. Locate trainer assigned by instructor.
2. Preoperational checks.
    a. Close all air line valves
    b. Check Master Switch for ON position.
    c. Check Air Compressor Switch for ON position
3. Connect the heating-cooling thermostat as shown in figure 7.

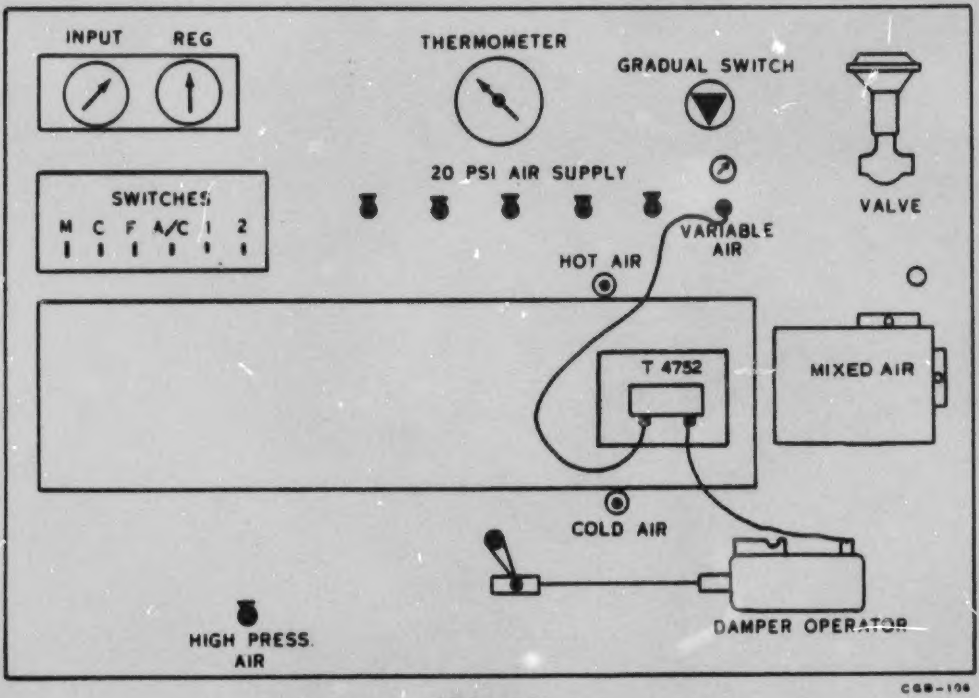
INPUT
REG
THERMOMETER
GRADUAL SWITCH
SWITCHES
M
C
F
A/C
1
2
20 PSI AIR SUPPLY
VARIABLE AIR
VALVE
HOT AIR
T 4752
MIXED AIR
COLD AIR
DAMPER OPERATOR
HIGH PRESS. AIR
CGB-106

Figure 7.

4. Apply 15 psig supply to the thermostat.

5. Check sensitivity.

6. Warm the lower sensing element by exhaling on it.

   a. Is this part of the controller direct-acting or reverse-acting?

   ____

   b. Would it be used for cooling or heating? ______________________

   Measure the ambient temperature:______________°F.

7. Adjust the set point ot the measured temperature.

8. Turn the heating calibration screw to midspring range of controlled device.

9. Increase the supply pressure to 19 psig using the gradual switch.

   NOTE: We will assume that the heating and cooling set points will be the same so the controller can be adjusted more simply. If you encounter a condition where they are not the same, refer to the service manual for the method of adjustment.

10. Turn the cooling calibration screw to obtain midspring range of controlled device.

11. Turn the dial to the desired value to be controlled ______________°F.

12. Turn on fan, heaters and air conditioner. Observe response of controller.

13. Shutdown procedures.

    a. Close air line valves.

    b. Disassemble hoses from regulators and controls.

    c. Check all switches for OFF position.

14. Replace cover.

15. Have instructor check your work.

Checked by ______________________
Instructor

CALIBRATION OF A PNEUMATIC NON-BLEED CONTROLLER

OBJECTIVE

To calibrate and adjust a non-bleed controller (RP-908A) and a temperature sensor (LP914).

PROCEDURES

Accomplish all preoperational checks listed below prior to operation of the trainer and observe the listed procedures closely during all operations.

PREOPERATIONAL CHECKS AND ADJUSTMENTS

1. Locate trainer assigned by the instructor.
2. Preoperational checks.
   a. Close all air line valves.
   b. Check Master Switch for ON position.
   c. Check Air Compressor Switch for ON position.
3. Connect the control loop as shown in figure 8.

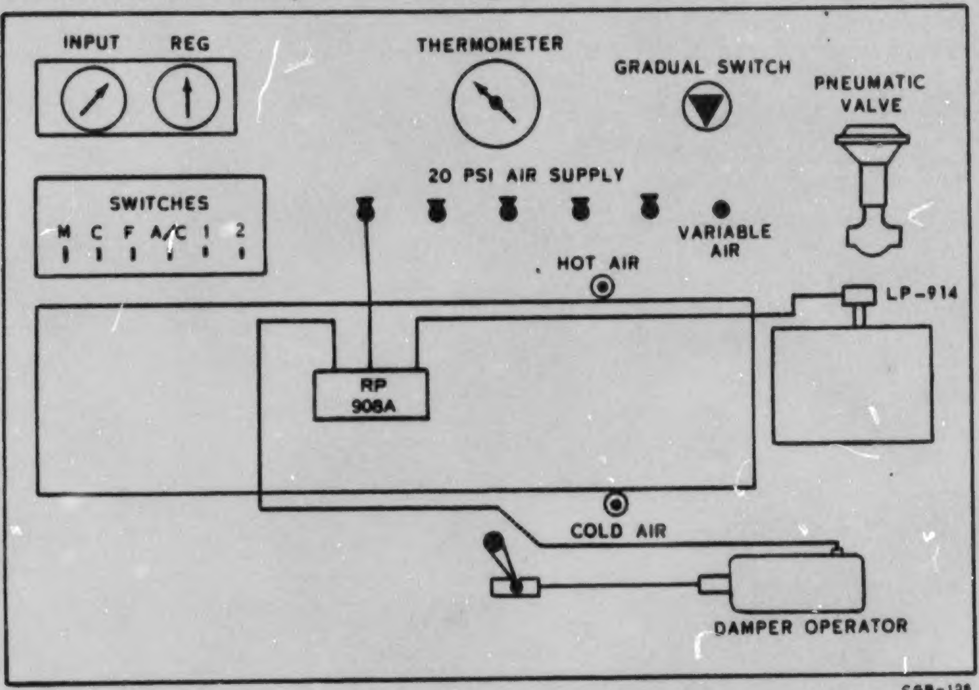
INPUT
REG
THERMOMETER
GRADUAL SWITCH
PNEUMATIC VALVE
20 PSI AIR SUPPLY
SWITCHES
M C F A/C 1 2
VARIABLE AIR
HOT AIR
LP-914
RP 908A
COLD AIR
DAMPER OPERATOR
CGB-136

Figure 8. 297

4. Remove cover from controller.

5. Apply 20 psi supply pressure.

CALIBRATION

1. Determine the action.

   a. Warm the sensor with your hand.

   b. Observe the branch line gage.

      (1) Did the pressure increase or decrease? ____________________

      (2) Is the controller direct or reverse action? ____________________action.

      (3) How can the action be changed? ____________________

      ____

2. Set the controller for direct action.

   NOTE: The two action springs are left disconnected when the controller is adjusted for direct action. Springs are connected for reverse action.

3. Adjust the proportional band setting for 5 percent P. B.

   NOTE: The main lever which has the P. B. adjustment knob has two P. B. scales. One scale is for direction action and the other for reverse action. When adjusting this setting, be sure the proper scale is used for the action the controller is set for.

   When the P. B. setting is 5 percent, what is the throttling range of this controller,

   having a -40 to 160°F range? ____________________°F.

4. Check the proportional band spring.

   NOTE: This spring is connected to the main lever when the proportional band setting is 15 percent and above.

   With a proportional band setting of 10 percent, is this spring connected? ________

5. Turn the set point adjusting screw to obtain midspring range of the controlled device.

6. Find the ambient sensed temperature of the sensor.

   a. Sensor temperature ____________________°F.

   b. Using the pneumatic temperature chart (figure 9), what pressure should

      Port No. 1 be indicating? ____

7. Loosen the scale plate screw and adjust scale with dial to indicate the sensed temperature.

PROPORTIONAL BAND CHECK

1. Turn the set point adjusting screw until 8 psi branch line pressure is obtained.

2. Note the temperature setting on dial. ______________________ °F.

3. Now, turn the set point adjusting screw until 13 psi branch line pressure is obtained.

4. Note the temperature setting on dial. ____________________ °F.

   NOTE: The temperature setting difference obtained with a 8-13 psi branch line pressure change should equal the proportional band setting.

5. If the proportional band setting is not correct, then readjust P. B. and recalibrate controller following calibration step procedure.

6. If the above check indicates a correct adjustment, the pneumatic controller is in calibration.

7. Turn the set point adjustment to a set point of 70° and the pneumatic sensor-controller will be in control.

8. Shutdown procedures.

   a. Close air line valves.

   b. Disassemble hoses from regulators and controls.

   c. Check all switches for OFF position.

9. Replace cover.

10. Have instructor check your work.

Checked by ______________________________
Instructor

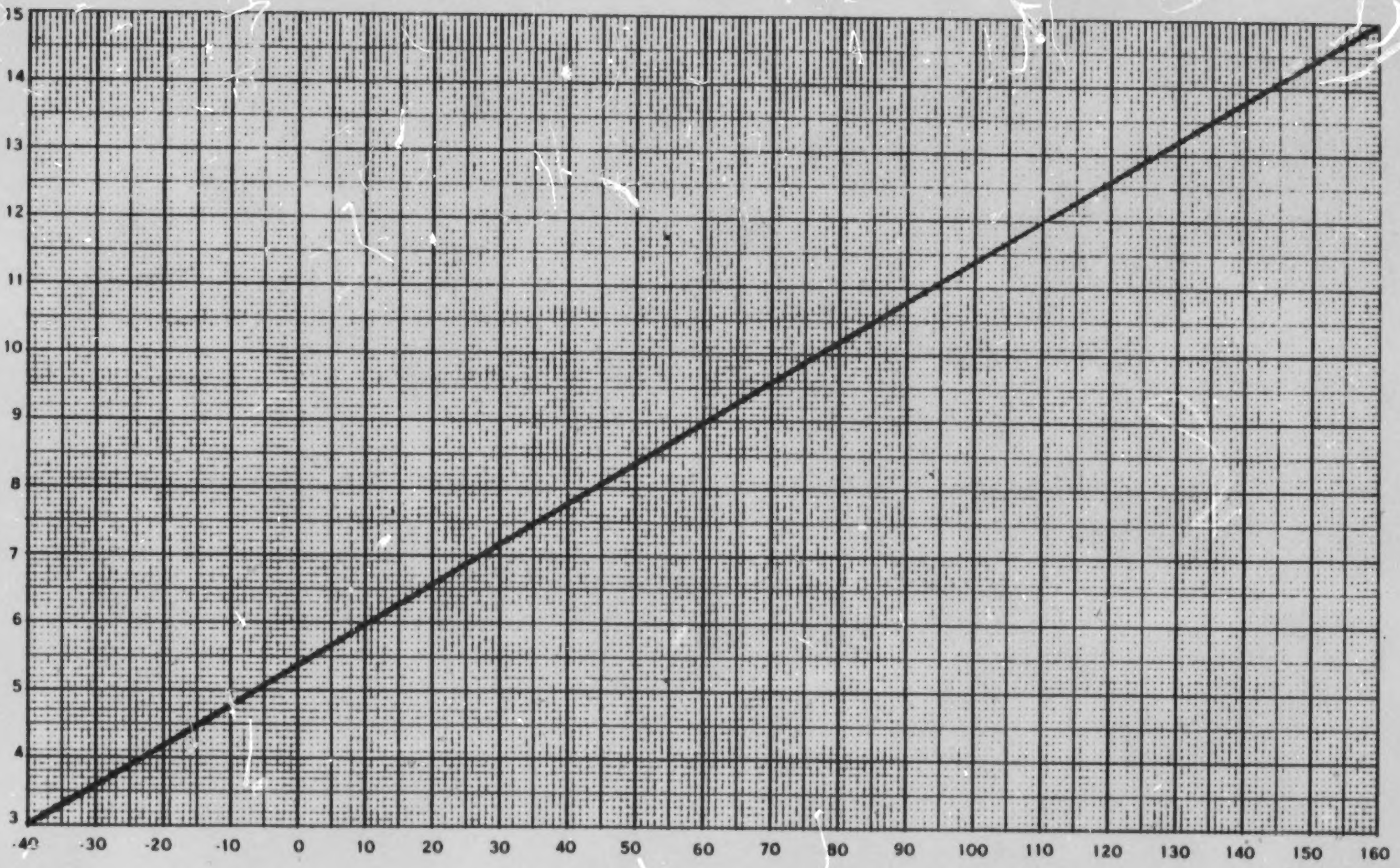

Figure 9. Pneumatic Temperature Chart

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STUDY GUIDES 3ABR54530-VII-4 thru 5

Department of Civil Engineering Training

Refrigeration and Air-Conditioning Specialist

ELECTRICAL AND ELECTRONIC CONTROLS

July 1975

SHEPPARD AIR FORCE BASE

11-8

Designed For ATC Course Use

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(Superseded publication may be used until stock is exhausted.)

Dept of Civil Engineering Training
Sheppard AFB, Texas

SG 3ABR54530-VII-4
July 1975

ELECTRIC CONTROLS

OBJECTIVE

1. To develop a knowledge and understanding of electric controls, their use, advantages, and applications.

2. To develop the skills necessary for the installation, calibration, and maintenance of electric control loops to include the following:

    a. Series 20, 40, and 80 Minneapolis-Honeywell controls.

    b. Series 60 and 90 Minneapolis-Honeywell controls.

INTRODUCTION

The applications of automatic controls range from simple domestic temperature control to precision control of industrial processes. Automatic controls can be used whenever a variable condition must be controlled. These conditions may be pressure, temperature, humidity or rate and volume of flow. Automatic controls are applied to refrigeration, air conditioning, heating, ventilation or a combination thereof. All automatic controls are to

1. Ensure that a desired condition is maintained.

2. Serve a safety function by keeping variable conditions within predetermined limits or by preventing mechanical equipment from operating when its operation would be hazardous.

3. Ensure economical control by providing operating cycles, or a level of system performance that matches load conditions.

4. Eliminate human error. A complete and properly designed automatic control system has the capability of interlocking and coordinating refrigeration, air-conditioning, heating, and ventilation systems in a manner impossible to accomplish with manual controls.

There are six basic functions that must be performed by the controls if the system is to be fully automatic. These functions and the units that perform them are

1. Function: Measure changes in one or more variable conditions.
   Performed By: Sensing or measuring element.

2. Function: Translate these changes into force or energy of a kind that can be used by the final control element.
   Performed By: Controller mechanism.

3. Function: Transmitting this energy to the point of corrective action.
Performed By: Electrical wiring, pneumatic piping and mechanical linkage.

4. Function: Use energy to position the final control element effecting a corrective change in the control variable.
Performed By: Controlled device or actuator, such as a valve or damper.

5. Function: Detect the completion of the corrective change.
Performed By: Sensing or measuring element.

6. Function: Terminate corrective change to prevent overcorrection.
Performed By: Controller mechanism, connecting piping, wiring and linkage, and the controlled device.

To a large degree, the type of energy which is best suited for a particular control problem determines the kind of control equipment selected. Electrical energy is commonly used to transmit the controller measurement of a change in a controlled variable to other parts of the system. It also translates that measurement into work at the final control element. For this purpose electricity has the following advantages:

- It is readily available.
- Electrical wiring is usually simple and easy to install.
- Electrical energy readily amplifies the relatively small signal received by the sensing element making it possible to control systems which ordinarily could not be controlled.
- The impulse received from the sensing element can be applied directly to produce one or several combinations or sequences in electrical outputs.
- It readily permits controlling from a remote point.

ELECTRICAL DEVICES

Before you can fully understand the operation of electrical controls you must first have a working knowledge of electricity, electrical circuits and electrical devices. For a review of these items consult SG 3ABR54530-II-2 and SG 3ABR54530-II-3 and 4. There are several devices which are commonly found in electric control circuits. We will briefly cover these items and their basic operations.

Switches

Switches are used to open and close circuits. The two main types of switches used in controls are snap acting and mercury bulb.

SNAP ACTING SWITCHES. These switches are constructed with fixed contacts securely attached to the thermostat base. These fixed contacts are mounted inside a permanent round magnet which provides a magnetic field in the area of the contacts. The movable contact is attached to a bimetal element. Upon a decrease in temperature it will move towards the fixed contact. As the contact enters the magnetic field, the magnetic field "pulls" this contact against the fixed contact with a positive snap. As the temperature increases the bimetal becomes warmer and wants to pull the movable contact away from the fixed contact. Because the movable contact is in the magnetic field, the bimetal does not (at this instant) have enough force to overcome the magnetic force. As the bimetal continues to warm and bend, it soon develops enough force to overcome the magnetic field. The movable contact breaks away with a positive snap. Figure 1 illustrates an SPST snap switch. Figure 2 illustrates an SPDT snap switch.

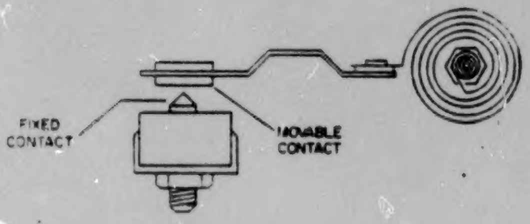

Figure 1. SPST Snap Acting Switch

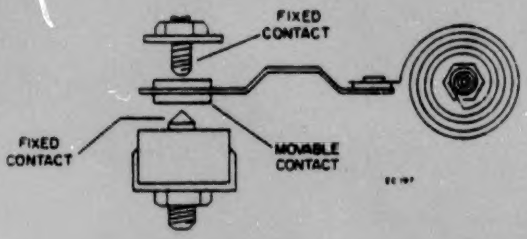

Figure 2. SPDT Snap Acting Switch

Controllers are supplied with dust covers to prevent dust and other contaminants from getting on the contacts. Should it become necessary to clean the contacts, use a clean business card or smooth thin cardboard. The card should be inserted between the contacts and gently pulled back and forth to remove the dirt or film. Never use a file or sandpaper for this purpose.

MERCURY SWITCHES. These switches perform the same switch actions as the snap acting, but in a different manner. The switching is accomplished by a globule of mercury moving between two or three fixed probes sealed within a glass bulb. The mercury bulb is attached to the thermostat bimetal. Figures 3 and 4 illustrate an SPST and an SPDT mercury switch. Figure 5 illustrates a mercury switch attached to the bimetal.

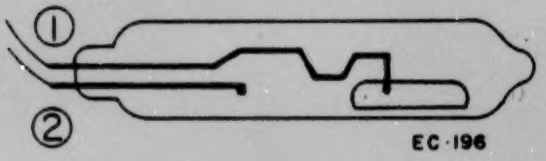

Figure 3. SPST Mercury Switch

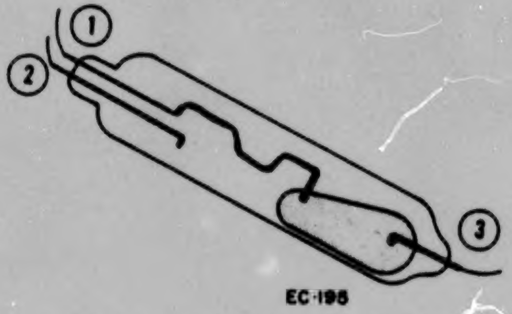

Figure 4. SPDT Mercury Switch

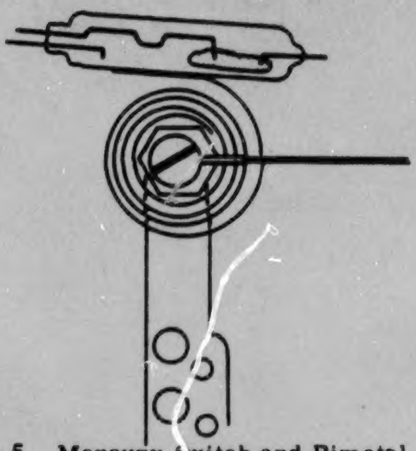

Figure 5. Mercury Switch and Bimetal

Control Transformers

In this study guide the term "line" voltage refers to the normal electric supply voltage which is usually in the range of 115 or 230 volts. Line voltage may be used directly or connected to the primary side of a stepdown transformer for a low voltage circuit. Most of the electrical controls we will discuss uses from 20 to 24 volts ac. The control transformer is used to obtain this low voltage supply. Figure 6 illustrates a multicoil multitap transformer used for this purpose.

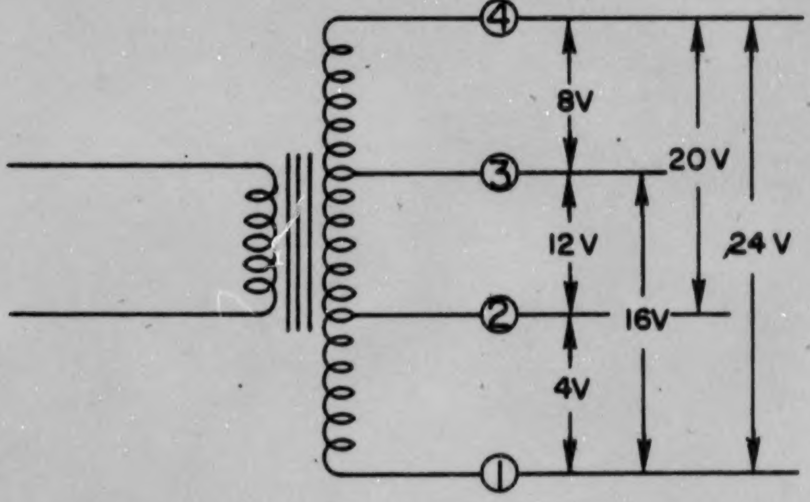

Figure 6. Control Transformer

TROUBLE ANALYSIS OF ELECTRICAL CONTROL SYSTEMS

Before you can effectively troubleshoot a control circuit or system, you should know the circuit and how it operates. You can find these items in the wiring diagram of the circuit, located on the inside of the controller cover or control panel cover. If the system does not operate properly, the circuit is defective and an analysis as to the type of trouble and its location must be made.

Types of Troubles

In practically all cases, the actual trouble will be one of the following types: an open, a short, or low power.

An open circuit is one that has a break in any part of the electrical circuit between the unit of resistance and the source of power. The effect of an open is that no current can flow so the unit is inoperative.

A short circuit is one in which a conductor makes contact with another conductor. A "hot" conductor touching a neutral conductor is called a "direct short." As you probably know, this will blow a fuse or trip the circuit breaker because there is no resistance in the circuit. When two different "hot" conductors come in contact with each other, it is called a "cross short." This can cause power to be applied even though power has been opened in one "hot" conductor.

Low power causes units to operate improperly. Two effects are sluggish motors and dim lights. Besides low voltage from the power source, low power can be caused by loose, dirty or corroded connections.

Location of Trouble

As soon as you have studied the wiring diagram, the next step is to locate the trouble by properly using a testing instrument.

Opens can be found in circuits with a voltmeter when the power is left on. Figure 7 shows the voltmeter indications of a control circuit that is operating properly. The readings in figure 8 show that thermostat switch has an "open." The switch is closed but the motor still is not operating.

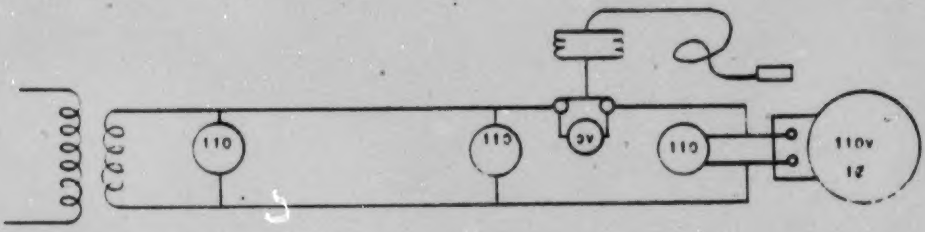

Figure 7. Normal Voltmeter Readings

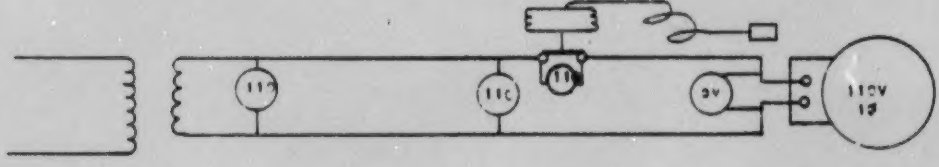

Figure 8. Voltmeter Readings Indicate an "Open" in the Thermostat

You can see from the contrast of figures 7 and 8 that the voltmeter readings will tell if the circuit is properly operating. It also tells where the existing trouble is located.

Opens may be located with any device which checks continuity, such as a continuity meter, continuity light or ohmmeter. These testers are used when power is OFF. An ohmmeter could be used in figure 8 to locate the open in the switch. With the power off, the ohmmeter would indicate infinity (∞) across the switch which means it is open.

Shorts are usually located with an ohmmeter. A direct short would blow the fuse or trip the circuit breaker; therefore, power cannot be applied to check with a voltmeter. A cross short in most cases would not blow a fuse, but a voltmeter would not tell if a cross short was present. The proper thing to do would be to isolate the circuit and check for continuity between the two wires.

The circuit in figure 9 has a direct short between L_1 and L_2. The blown fuse indicates there may be a direct short. The ohmmeter indicates a direct short because it reads zero resistance. A reading of infinity would have indicated there was no short. A cross short would be located in the same manner.

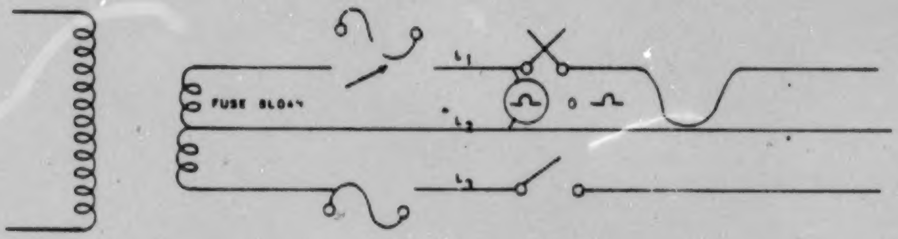

Figure 9. Direct Short

The same procedure is used to locate troubles in three- and four-wire systems. The main thing is to study the wiring diagram and determine how the circuit should operate. The trouble can be located with the proper instrument as you use your knowledge of locating troubles.

ELECTRICAL CONTROL LOOPS

The following table classifies and describes the Minneapolis-Honeywell control circuits as shown in figure 10.

SERIES	CONTROLLER	SIGNAL CIRCUIT	ACTUATOR	CONTROL MODE
20	Makes one circuit to start, breaks it and makes a second circuit to stop.	Three-wire, low voltage.	Any Series 20 device.	Two-position.
40	Makes circuit when switch is closed, breaks it when switch is open.	Two-wire, line voltage.	Any Series 40 device.	Two-position.
60 Two-position	Line voltage equivalent of Series 20.	Three-wire line voltage.	Series 60 two-position control motor.	Two-position.
60 Floating	Line or low voltage floating control. (Similar to modulating action)	Three-wire.	Series 60 floating motor.	Single speed floating.
80	Low voltage equivalent of Series 40.	Two-wire, low voltage.	Any Series 80 motor or solenoid.	Two-position.
90	Modulating action (proportional)	Three-wire, low voltage.	Any Series 90 motor.	Proportional.

Figure 10. Minneapolis-Honeywell Control Circuits

Series-20 Control Circuit

The series-20 control circuit is designed for low voltage, two-position control of

1. motorized valves
2. motorized dampers.

Series-20 control circuits are not "fail-safe" and should not be used where continued operation of the controlled equipment would be hazardous if the power failed. Series-20 motors (and equipment under their control) remain in whatever position they happen to occupy at time of power failure. The valve has provisions whereby it may be positioned manually by use of an Allen wrench.

The series-20 control circuit consists of one holding and two starting circuits. The motor rotates in one direction only, making a half turn (180°) each time one of the starting circuits and holding circuits are completed. A cam and switch arrangement on the motor shaft makes the holding circuit at the beginning and breaks the holding circuit at the end of the 180° shaft travel. To obtain two-position operation, the motor and circuit are constructed so that once the motor is started it cannot stop until it has rotated a full half turn or 180°.

Figure 11 illustrates a complete series-20 control loop used to control room temperature utilizing a steam radiator. The equipment includes a 24-volt transformer, a series-20 thermostat, and a series-20 motorized valve.

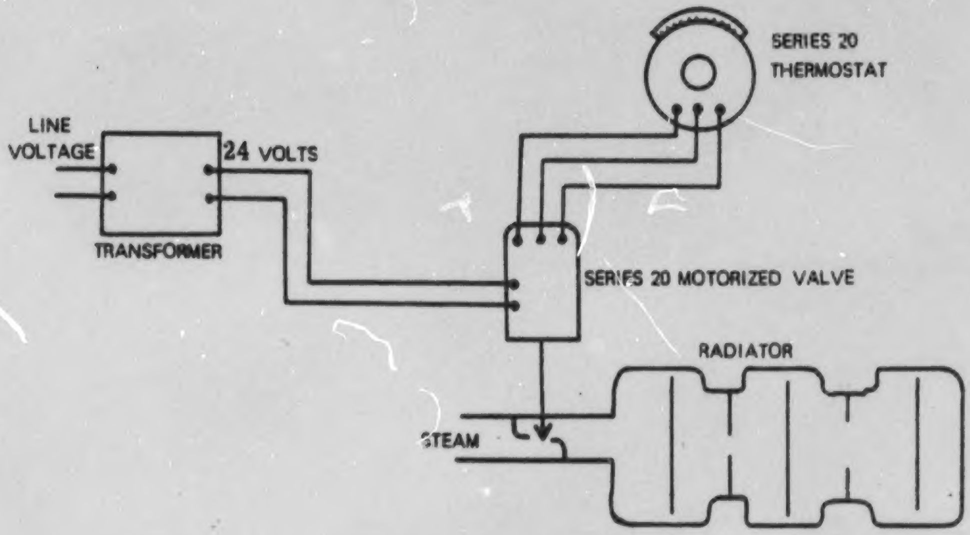
SERIES 20
THERMOSTAT
LINE
VOLTAGE
24 VOLTS
TRANSFORMER
SERIES 20 MOTORIZED VALVE
RADIATOR
STEAM

Figure 11. Series-20 Control Loop

Series-20 Operation

The thermostat is constructed with a bimetal blade which engages the blue contact on a drop in temperature and the white contact on a rise in temperature. In figure 12 the blade is shown in the satisfied position. The maintaining switch cam and contacts, the motor, gear train and crank arm are symbolically shown. The following figures show the progressive completion of the circuit.

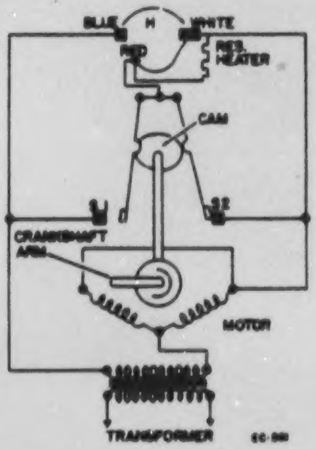
BLUE
H
WHITE
RED
RES.
HEATER
CAM
S1
S2
CRANKSHAFT
ARM
MOTOR
TRANSFORMER

Figure 12. Complete Basic Series-20 Control Circuit

In the shaded diagrams that follow a solid white line labeled indicates that maximum current is flowing through that part of the circuit; a broken white line labeled indicates that negligible current is flowing through that labeled part of the circuit; and a solid black line labeled indicates inactive portion of the circuit.

TEMPERATURE DROP

1. The thermostat blade engages the Blue contact.

2. The starting circuit is CLOSED.

3. The motor is energized and begins to rotate clockwise.

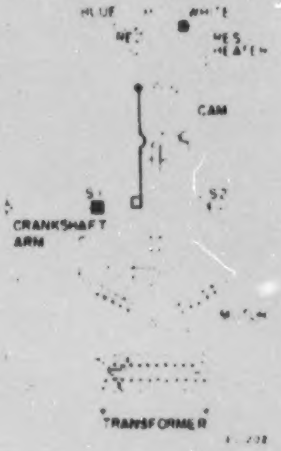
BLUE
H
WHITE
RED
RES.
HEATER
CAM
S1
S2
CRANKSHAFT
ARM
MOTOR
TRANSFORMER

Figure 13.

HOLDING CIRCUIT ESTABLISHED

As the motor and cam rotate:

1. The left blade of the maintaining switch makes contact with S1 and the holding circuit is closed. The holding circuit is independent of the starting circuit and once made, will furnish current to the motor regardless of the action of the thermostat.

2. If the thermostat continues to hold the Blue contact closed, a small amount of current will flow through it. Most of the current will flow through the holding circuit because it offers the path of least resistance

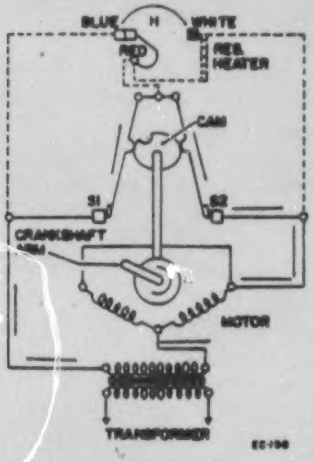
BLUE
H
WHITE
RED
RES.
HEATER
CAM
S1
S2
CRANKSHAFT
ARM
MOTOR
TRANSFORMER
EE-196

Figure 14.

HOLDING CIRCUIT BROKEN

When the motor shaft has rotated 180 degrees:

1. The cam breaks contact S2.
2. All circuits are opened.
3. The motor stops.
4. Negligible current passes through the heater resistance; current is insufficient for motor travel.

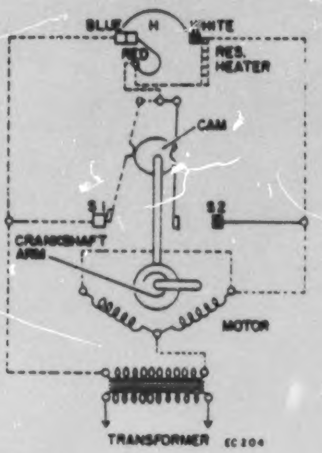
BLUE
H
WHITE
RED
RES. HEATER
CAM
S1
S2
CRANKSHAFT ARM
MOTOR
TRANSFORMER
EC 204

Figure 15.

TEMPERATURE RISE

Both temperature rise in the controlled space and heat from the resistance heater causes these actions:

1. The thermostat blade moves to the right and engages the White contact.
2. The starting circuit is closed.
3. The motor starts to rotate clockwise.

The additional heat provided by the resistance heater causes the thermostat to close R to W sooner than normal. This action tends to smooth out the "overshooting swings" which prevail in simple two-position control.

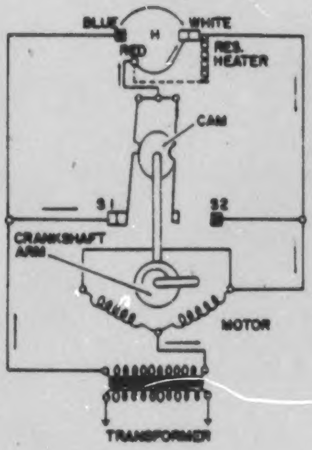
BLUE
H
WHITE
RED
RES. HEATER
CAM
S1
S2
CRANKSHAFT ARM
MOTOR
TRANSFORMER

Figure 16.

HOLDING CIRCUIT REESTABLISHED

1. The right blade of the maintaining switch makes contact with S2.

2. The motor continues to rotate until it has made a 180° turn.

When the motor has completed the 180° turn, the holding circuit is again broken at contact S1 and the motor stops. It has then completed a cycle.

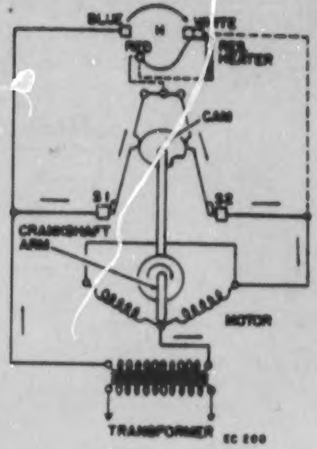

Figure 17.

Series-40 and Series-80 Control Circuits

The series-40 and -80 are the simplest of the Minneapolis-Honeywell control circuits; their control combinations are also very simple. The series-40 and -80 control circuits act to make and break an electrical circuit which results in two-position response.

Series-40 and -80 controllers include the following: room thermostats, insertion thermostats, pressure controllers and humidity controllers.

The series-40 control circuit is a line voltage circuit and the series-80 is a low-voltage circuit. Both are switched directly by the SPST switching action of the series-40 or -80 controller. These controllers may have either open contacts or mercury switches. In most cases they are snap acting. As was stated earlier this controller is two-position and requires two wires and can be used to control fans, lights, electric motors, and other standard line or low-voltage equipment as well as the series-40 or -80 motors.

Series-40 and Series-80 Operation

The equipment under control is energized when the controller switch is closed and deenergized when it is opened. This arrangement is very simple in principle. Figure 18 shows a basic circuit.

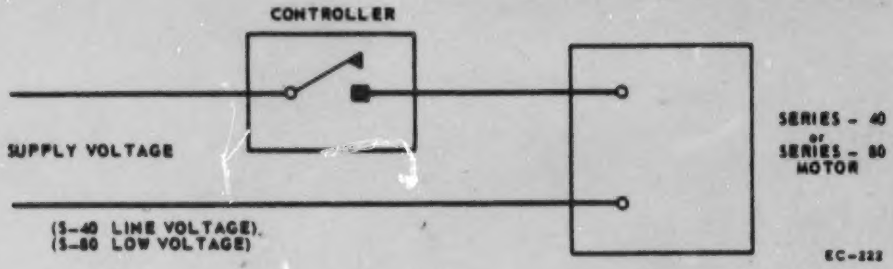

Figure 18.

Figure 19 shows a complete series-40 or series-80 control loop. It includes a controller, control motor, control device, and a power supply. The thermostat is sensing the temperature of the water. A drop in temperature below the set point causes the mercury bulb to rotate, allowing the mercury to close the circuit to the motor winding and the brake solenoid coil. As the motor turns, the valve will open and allow steam to enter. The motor is equipped with a spring which winds up as the motor operates and the shaft turns. At the end of the power stroke, a cam assembly opens the limit switch and the motor stops. The motor is held in the extended position by the brake solenoid, as long as the controller keeps the circuit closed. As the temperature of the water rises the mercury bulb will rotate once again, in the opposite direction. When the controller breaks its circuit (or when a power failure occurs) the brake solenoid circuit is broken and the spring failure occurs) the brake solenoid circuit is broken and the spring winds the motor to the deenergized or normal position. For this reason the series-40 and the series-80 motors are FAIL-SAFE

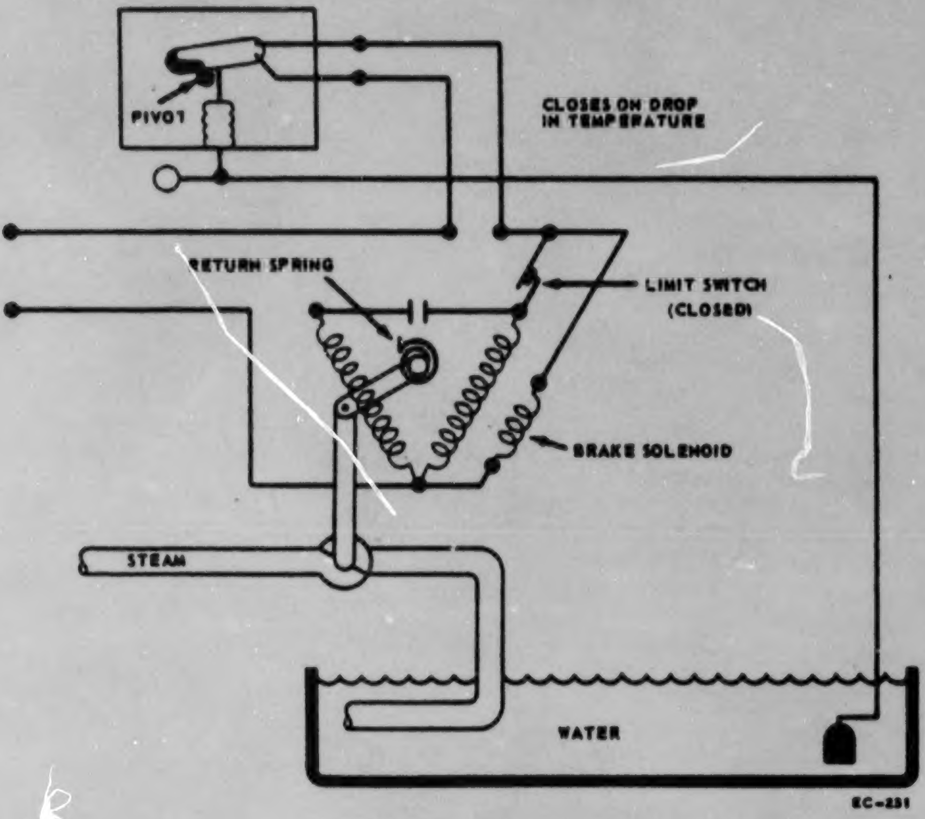
PIVOT
CLOSES ON DROP IN TEMPERATURE
RETURN SPRING
LIMIT SWITCH (CLOSED)
BRAKE SOLENOID
STEAM
WATER
EC-231

Figure 19. Series-40 or -80 Control Loop

Series-60 Control Circuits

The series-60 control circuits make and break electrical circuits which results in two kinds of responses--two-position, figure 20; or floating, figure 22.

SERIES-60 TWO-POSITION CONTROL CIRCUIT. The series-60 two-position control circuit is similar to the series-20 except that series-60 is a line voltage circuit It can be used for:

1. Industrial applications using line voltage equipment.

2. Installations where single-pole double-throw (SPDT) control of line voltage is needed.

A series-60 two-position control circuit is not "fail-safe" and should not be used where continued operation of the controlled equipment would be hazardous if the control circuit power should fail. Series-60 two-position motors (and equipment under their control) remain in the position they happen to be in at power failure.

The basic series-60 two-position control circuit can be obtained by combining a series-60 two-position motor and a series-60 two-position controller.

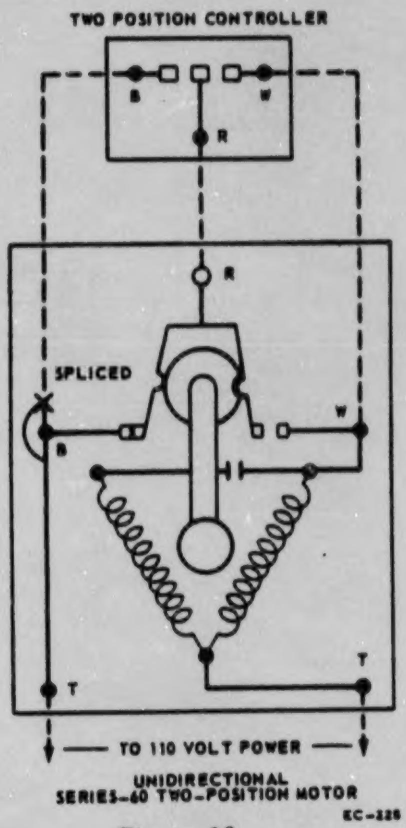

Figure 20.

SERIES-60 FLOATING CONTROL CIRCUIT. The series-60 floating control produces a response that is different from two-position response. Floating controls are usually applied to the following:

1. Motorized valves as used on tank level control systems, figure 21.

2. Motorized dampers for static pressure regulation, figure 22. (Static pressure regulation will be used to demonstrate the operation of the series-60 floating control loop.)

There is no fixed number of positions in floating control, as it is intended that the final control element, such as a valve or damper, be allowed to assume any position between its two extremes (fully open to fully closed) as long as the controlled variable remains between the limits of the controller.

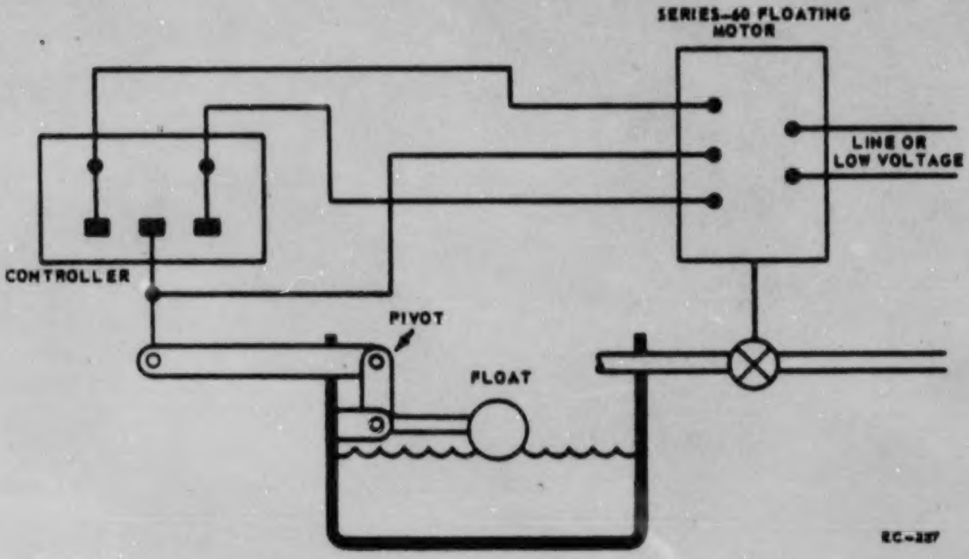
SERIES-60 FLOATING MOTOR
LINE OR LOW VOLTAGE
CONTROLLER
PIVOT
FLOAT
EC-337

Figure 21. Tank Level Control

Series-60 Floating Operation

Figure 22 illustrates a complete series-60 floating control circuit. The equipment includes the following:

1. A static pressure controller; a control especially designed to measure and control extremely small pressures, such as in an air-conditioning duct or PMEL room.

2. A series-60 floating control motor.

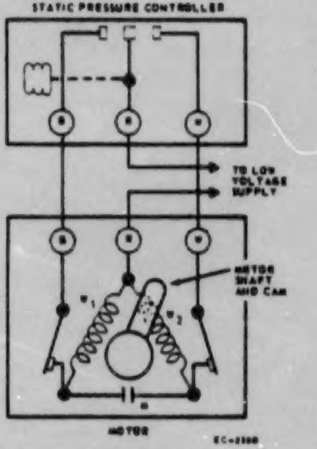
STATIC PRESSURE CONTROLLER
TO LOW VOLTAGE SUPPLY
MOTOR SHAFT AND CAM
W1
W2
MOTOR

Figure 22. Complete Series-60 Floating Control Circuit

A wiring diagram of the power unit showing the coils W1 and W2, capacitor M, and the circuit connections will be found in figure 23. The common, or Red, terminal is connected to one side of the powerline. When the other side of the powerline is connected to either the White or the Blue terminal, the motor will run. The direction of rotation depends on which terminal the powerline is connected to. Thus the motor can be reversed by the switching action of the controller as it directs the power to either the White or Blue terminal when a corrective action is desired at the final control element.

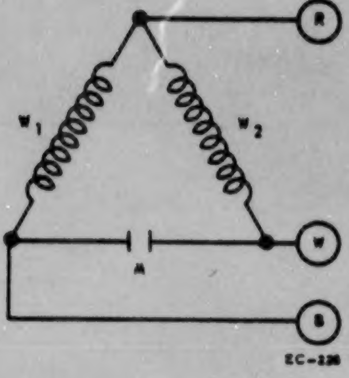

Figure 23. Diagram of the Internal Circuit of the Series-60 Motor

If the controller is positioned so that the White terminal is energized, the current will pass directly through the W2 winding. Current also flows through the W1 winding but must first flow through the capacitor M. The phase of the current through W2 is shifted relative to that through W1 and the motor will turn in a corresponding direction. When the controller switch is positioned so that the Blue terminal is energized, the phase is shifted in the other direction and the motor is reversed. When no power is furnished to either the Blue or White terminal, the motor remains stationary.

Limit switches are included in floating motors so that the White and Blue circuits can be opened when the motor shaft reaches the end of its travel. The rotation of the motor crank arm is usually limited to 160 degrees in this way.

1. On a drop in pressure:

    a. The controller blade contacts the Blue terminal, making Red to Blue

    b. The Blue terminal of the motor is energized.

    c. The motor turns in the direction which will establish a corrective action of the final control element.

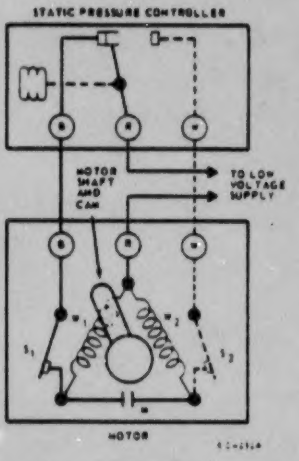

Figure 24. Pressure Drop

2. If the pressure drop cannot be immediately corrected by the floating action of the controller:

   a. The motor continues to drive the final control element toward the corrective position until it reaches the end of its travel.

   b. The limit switch S1 is opened by the motor cam and the circuit is deenergized.

   c. The motor stops.

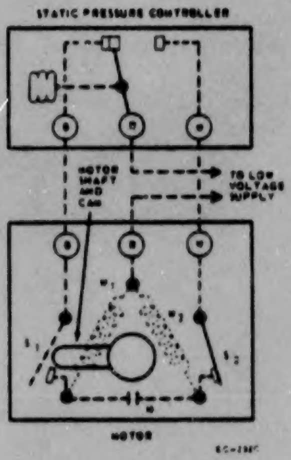

Figure 25. Sustained Pressure Drop

3. Rise in pressure

On a rise in pressure, the controller blade makes contact with the White terminal. The motor then turns in the other direction until it has corrected the pressure rise or until it has reached the end of its travel and opened the limit switch S2.

When the controller blade is moving between the Blue and White contacts, the motor is deenergized. The circuit remains deenergized as long as the pressure stays between the upper and lower limits of the controller neutral zone.

Series-90 Control Circuit

The series-90 control circuit supplies modulating or proportioning control action and may be applied to:

1. Motorized valves
2. Motorized dampers
3. Sequence switching mechanisms

The circuit operates to position the controlled device at any point between fully open and fully closed, which will proportion the delivery of the agent to the immediate need as indicated by the controller.

Modulating control is not subject to the same operating limitations as the two-position or floating controls.

1. **Two-Position:** The two-position control circuit produces cycling, an on-off or open-closed control. It will not control a close variable as the modulating control. There is overshooting and undershooting beyond the desired differential. There is a time lag between the controller and the control device. Once the controller calls for control agent, it then must wait until it senses the change produced before it can react once again. Figure 26 graphically illustrates the operation of the two-position control circuit.

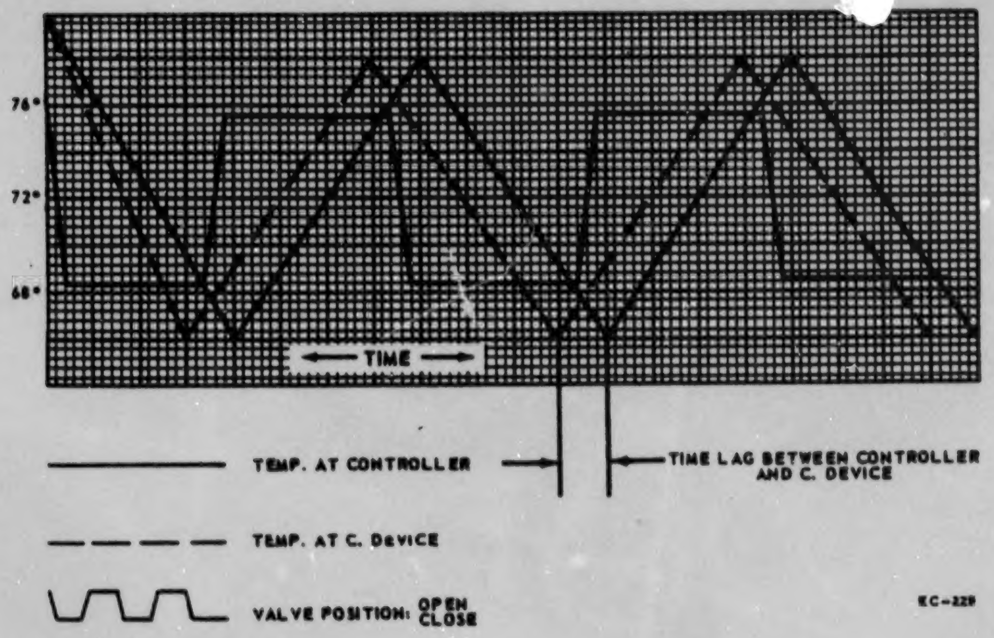

Figure 26. Two-Position Control Circuit Graph

2. Floating: The floating control circuit eliminates cycling, in that the final control element can take any position between fully open and fully closed. Overshooting and undershooting is not a problem with the floating controls, because the variable is kept within the range of the differential. A time lag still exists between the controller and the control device. Once agent has been supplied it may take 120 seconds or more before the change produced will be sensed and reacted to by the controller. Figure 27 will illustrate the floating control circuit.

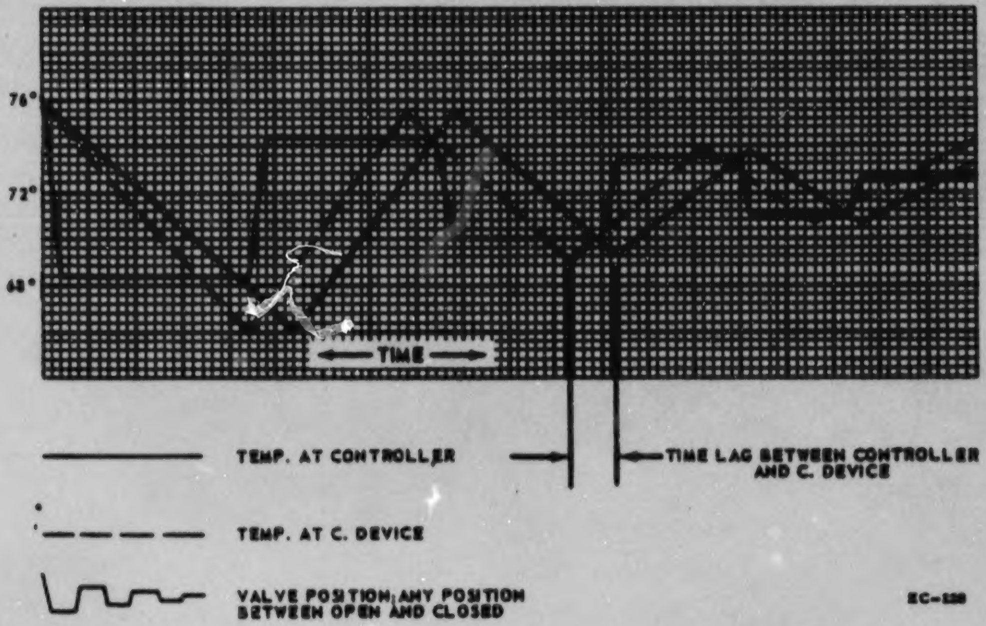

Figure 27. Floating Control Circuit Graph

3. Modulating: The term "modulating" refers to electrical control circuits. The term "Proportional" refers to pneumatic control circuits. They produce the same type of control, for they both have feedback: pneumatic feedback, produced by the feedback chamber in the pneumatic relay; and mechanical feedback, produced by the balancing potentiometer in the series-90 control cicuit. From figure 28 you will see that the modulating control circuit produces a very close control of the variable. Overshooting and undershooting is minimum. The lag time between the controller and the control device is also minimum. Figure 29 illustrates a mechanical link between the controller and the final control element.

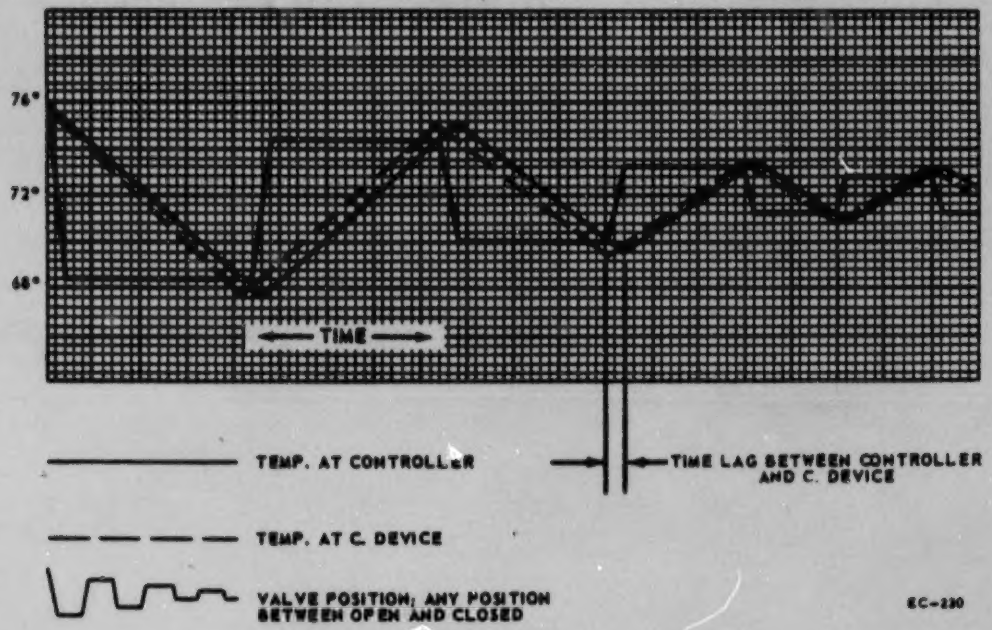

Figure 28. Modulating Control Circuit Graph

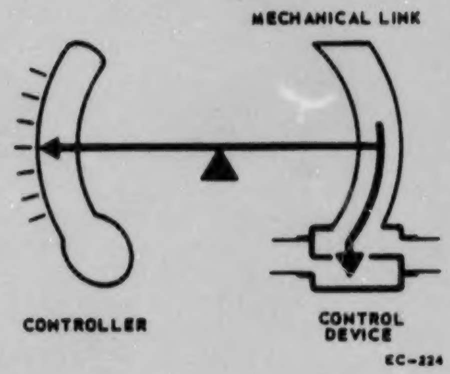
MECHANICAL LINK
CONTROLLER
CONTROL DEVICE
EC-224

Figure 29. Modulating Control Feedback

Series-90 Controllers

Before you can fully understand the series-90 controller, you must understand the operation of a potentiometer. A potentiometer is a variable resistor. Figure 30 illustrates this component which is a number of turns of resistance wire wound on a cylinder and constructed with three connections. The center connection is a movable finger or wiper which rides over the length of the coil completing the circuit wherever it touches. The wiper can be positioned manually or automatically, by the sensing element responding to a variable change.

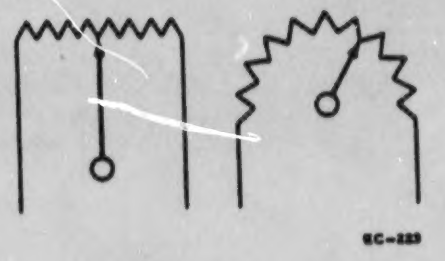

Figure 30. Potentiometers

Series-90 Circuits

The series-90 control loop consists of two circuits. Each of them has a specific junction in the overall operation of the series-90 control loop.

1. Control circuit: Figure 31 illustrates a modification of the Wheatstone bridge. It consists of two potentiometers. One potentiometer is in the controller and its wiper is moved by the sensing element reaction to each variable change. The other potentiometer is located in the motor and its wiper is moved by the rotation of the motor. You will note that the control circuit also contains two coils and a 24-volt power source. As shown, the thermostat is satisfied and the bridge is balanced. Power (24 volts) is applied to the bridge by the transformer. There are two paths for current to flow. The left circuit has a total of 135 ohms resistance plus coil C_1. The right circuit has a total of 135 ohms resistance plus coil C_2. The amount of current flow is equal in both circuits. This is called a balanced bridge.

2. Motor Circuit: The series-90 motor consists of a reversible capacitor-type motor unit and a balancing relay. Figure 32 illustrates how a balancing relay is constructed. The motor is started, stopped, and reversed by the SPDT contacts of the balancing relay. The relay consists of two solenoid coils and a U-shaped armature. The armature is pivoted in the center and each leg extends into the hollow core of each solenoid coil. A contact arm is fastened to the armature in such a manner that one or the other of the two stationary contacts may be engaged as the armature is moved back and forth on its pivot. When the relay is in a balanced condition, as shown in figure 32, the contact arm floats between the two stationary contacts and the motor is at rest.

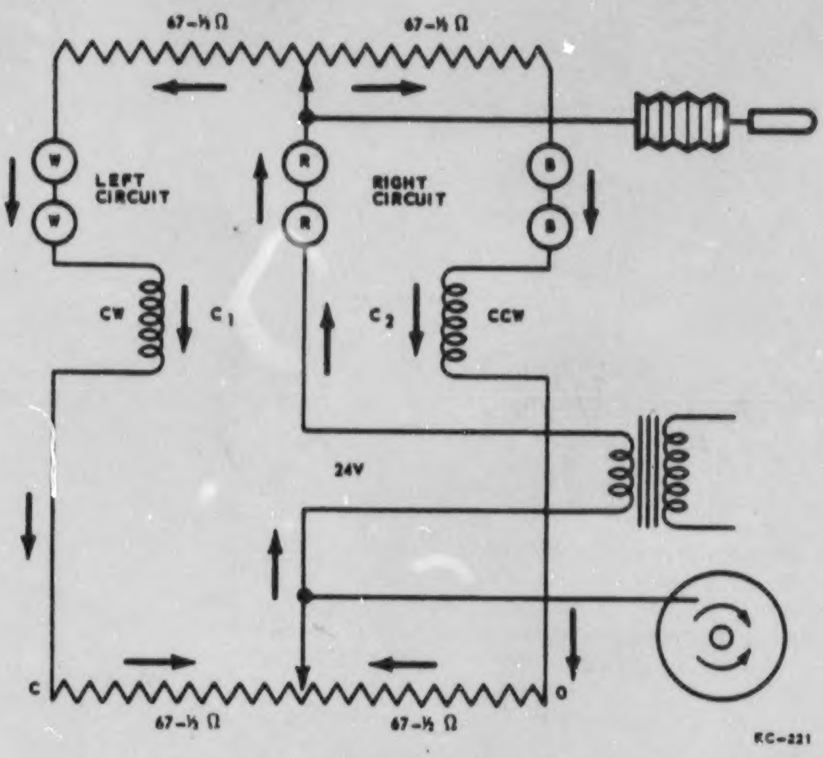
67-½ Ω
67-½ Ω
W
W
LEFT CIRCUIT
R
R
RIGHT CIRCUIT
B
B
CW
C1
C2
CCW
24V
C
O
67-½ Ω
67-½ Ω
EC-221

Figure 31. Series-90 Control Circuit

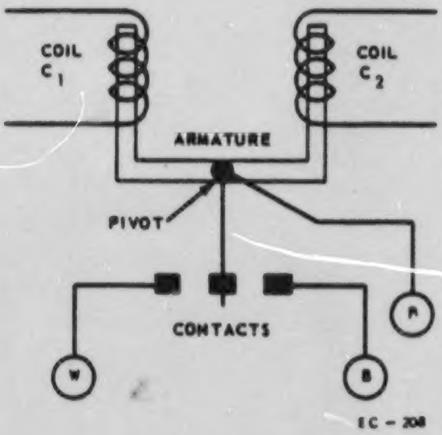
COIL C1
COIL C2
ARMATURE
PIVOT
CONTACTS
W
B
R
EC - 208

Figure 32. Diagram of a Balancing Relay

Series-90 Operation

Changes in conditions at the controller offsets the control circuit so that the amount of current flowing through the two relay coils is not identical. Whenever the current through these two coils becomes unbalanced, one of them becomes stronger and the U-shaped armature is moved.

The movement of the armature closes one of the relay contacts which in turn starts the motor running in the proper direction. If coil C_1 becomes stronger the contact blade is moved to the left making a circuit from one side of the transformer directly to motor windings W_1. Current is also supplied to W_2 through the capacitor. The motor operates in one direction until the bridge is balanced. At this time the contacts of the balancing relay is broken.

If coil C_2 becomes the stronger the right-hand contact is made and W_2 windings are directly powered while winding W_1 is powered through the capacitor. The motor is again energized but now in the opposite direction.

Figures 33, 34, and 35 are diagrams of the series-90 control circuit at work in various modes of operation.

Figure 33 shows an instantaneous condition in which the current is flowing from the transformer, through the potentiometer pointer, and down through both legs of the circuit. In the positions shown, the thermostat potentiometer pointer and the motor balancing potentiometer pointer divide their respective coils so that R1 = R4 and R2 = R3. Therefore R1 + R3 = R2 + R4 and the resistances on both sides of the circuit are equal. The coils C1 and C2 of the balancing relay are equally energized and the armature of the balancing relay is balanced. The contact arm is floating between the two contacts, no current is going to the motor, and the motor is at rest.

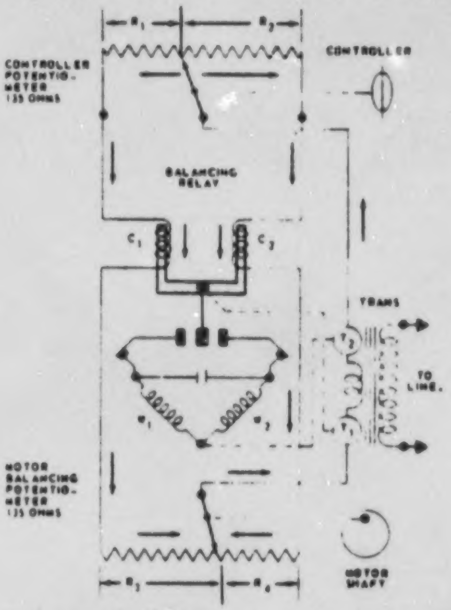

Figure 33. Diagram of a Series-90 Control Circuit in Balanced Condition

317

Figure 34 shows another instantaneous condition in which the temperature had decreased a small amount. As a result, the pointer of the thermostat potentiometer has moved toward the right end of the potentiometer coil. The amount of resistance on both sides of the circuit is no longer equal (R1 + R3 is greater than R2 + R4). The greater share of the current now flows through the right leg of the circuit and coil C2 of the balancing relay exerts a greater force on the armature than does C1. The armature has rotated, making contact to the side of the circuit that sends current directly to motor winding W2. The motor is running in the corresponding direction and moving the motor balancing potentiometer to a new position.

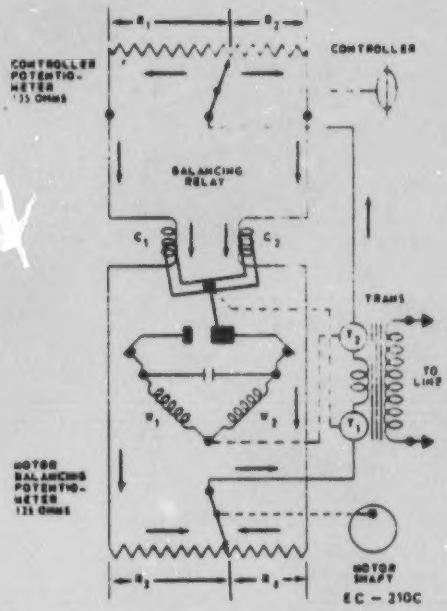
R1
R2
CONTROLLER POTENTIOMETER 135 OHMS
CONTROLLER
BALANCING RELAY
C1
C2
TRANS
T2
T1
TO LINE
W1
W2
MOTOR BALANCING POTENTIOMETER 135 OHMS
MOTOR SHAFT
R3
R4
EC - 210C

Figure 34. Diagram of Series-90 Control Circuit on Drop in Temperature. The circuit is Unbalanced.

Figure 35 shows an instantaneous condition after the motor shaft has moved the motor balancing potentiometer to a position which equalizes the current passing through the two legs of the circuit. In this condition, the right side of the thermostat potentiometer has a resistance equal to that of the left side of the motor balancing potentiometer. Likewise, the resistance of the left side of the thermostat potentiometer is equal to that of the right side of the motor balancing potentiometer. Again, R1 + R3 = R2 + R4, current flowing through the two legs of the circuit is equal, and the motor is at rest.

By careful analysis of the diagrams, it will be seen that the motor runs until the pointer of the motor balancing potentiometer reaches a position which corresponds to the position of the pointer of the thermostat potentiometer.

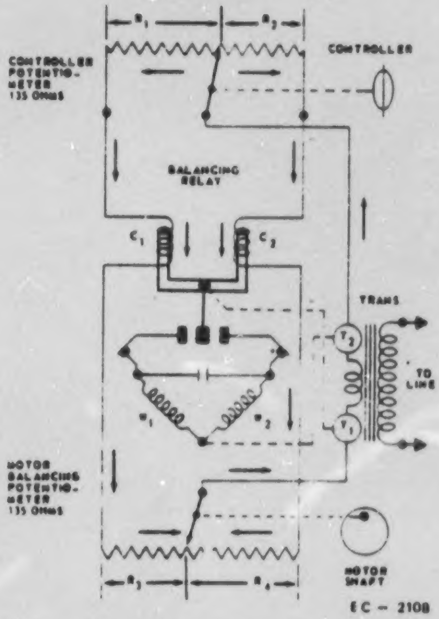
R1
R2
CONTROLLER POTENTIOMETER 135 OHMS
CONTROLLER
BALANCING RELAY
C1
C2
TRANS
T2
T1
TO LINE
W1
W2
MOTOR BALANCING POTENTIOMETER 135 OHMS
MOTOR SHAFT
R3
R4
EC - 210B

Figure 35. Diagram of Series-90 Circuit Rebalanced in New Position

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SUMMARY

The purpose of electrical controls is to control temperature, pressure, or humidity.

The types of switches that are used are SPST and SPDT: snap acting or mercury bulb.

Series-20 control loop is a low voltage, two-position control circuit. Series-40 is line voltage and series-80 is a low voltage circuit. Both are two-position. The series-60 control loop is either two-position or floating and can use either line or low voltage. The series-90 is a low voltage, modulating control loop, used primarily for close variable control.

QUESTIONS

1. Automatic controls are designed to be used on what systems?

2. What are the operational steps of an SPDT snap acting switch?

3. What is the main advantage of the mercury bulb switch over other types of switches?

4. When troubleshooting with an ohmmeter, an open is indicated by what type of reading?

5. What are the common causes of low power in electrical control circuits?

6. What are the disadvantages of the series-20 control circuit?

7. What is the main application of the series-20 motorized valve control circuit?

8. How can a series-20 control loop be changed from heating control to cooling control?

9. What type of motor is used in the series-20 motorized valve assembly?

10. What voltage is used on the series-20 motorized valve?

11. The series-20 valve has been changed for a cooling control system. What would be the result if the blue lead developed an open when it came in contact with the red lead?

12. The series-20 valve is in the heating mode. What would be the result if the blue lead developed an open when it came in contact with the red lead?

13. In the series-20 control circuit, what starts the motor? What stops the motor?

14. What type of switching actinn is used on the series-20 controller?

15. What is the purpose of the stepdown transformer, when used in the series-20 control circuit.

16. What would happen if we had a power loss on a series-20 electrical system while it is in operation?

17. Can an SPDT switch used on a two-position control loop complete two circuits at the same time? Explain.

18. In what direction of rotation does the series-20 motor turn?

19. On an increase in temperature in the heating cycle for a series-20 what would the "red" lead come in contact with?

20. What is the voltage required for a series-40 motor, for a series-80 motor?

21. While in operation, if the source of power is removed from the series-60 motor, what would the result be?

22. What is the purpose of the limit switches in the series-60 floating motor?

23. What type responses are the series-60 controllers used for?

24. Systems requiring fast reaction to any variable change used what type of series-60 control circuit?

25. What type of switching action is used in the series-60 controller?

26. What is the voltage required on the series-60 floating motor?

27. While in operation, if the brake solenoid in the series-40 motor develops an open, what would be the result on motor operation?

28. What is meant by the term "fail-safe"?

29. What is the switching action of the series-40 controller?

30. What type of motor is used in the series-60 floating control loop?

31. In the series-60 control loop what starts the motor?

32. If the blue lead was in contact with the red lead on the series-60 system, what would be the result if the blue lead developed an open?

33. Does the series-40 motor contain two limit switches? Explain.

34. What is the voltage requirement for the series-80 motor?

35. Does current flow through a balanced series-90 bridge? Explain.

36. What is the voltage required on the series-90 control loop.?

37. What type motor is used in the series-90 control circuit?

38. What would be the result if the white lead developed an open in the series-90 control circuit?

39. What controls the balancing relay in the series-90 control loop?

40. If the signal wiper arm in the series-90 controller became insulated from the resistor, what would be the result?

41. What is an advantage of modulating controls over two-position?

42. What is meant by modulation control loop?

43. What type switching action does the series-90 balancing relay contain?

44. On an increase in temperature the red lead of the series-90 controller will contact what lead?

45. What are the two electrical circuits in the series-90 control loop? Explain the function of each.

REFERENCES

1. AFM 52-7, Elementary Electricity
2. Reference Manual (Electric) for the Installer and Serviceman, Minneapolis-Honeywell Regulator Company
3. Engineering Manual of Automatic Control, Minneapolis-Honeywell Regulator Company

ELECTRONIC CONTROLS

OBJECTIVE

This study guide will aid you in learning electronics as applied to refrigeration and air-conditioning control systems.

This information is presented under the following topics:

- VACUUM TUBES
- SOLID STATE SEMICONDUCTORS

INTRODUCTION

Electronic controls are being used more each day. Temperature, pressure, and humidity can be controlled electronically. The major components of an electronic circuit are the vacuum tube or the semiconductor.

You will be required to inspect, adjust, troubleshoot and replace electronic controls. To do this you must know the construction characteristics, operating principles, and limitations of both the vacuum tube and the solid state semiconductor.

VACUUM TUBES

The main difference between a vacuum tube and other electrical equipment is that the current in a vacuum tube does not flow through a conductor, but through empty space--a vacuum. This is possible when "free electrons" are introduced into the vacuum.

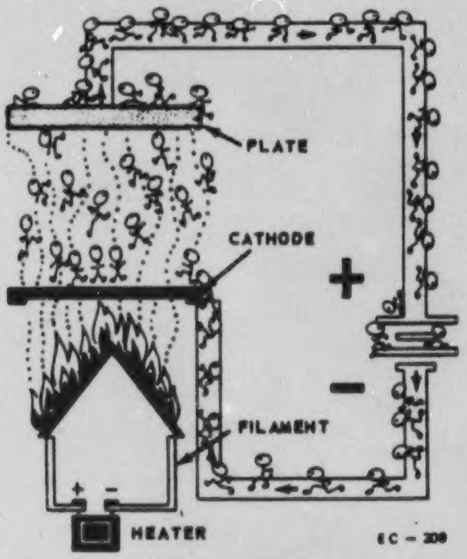


Figure 36.

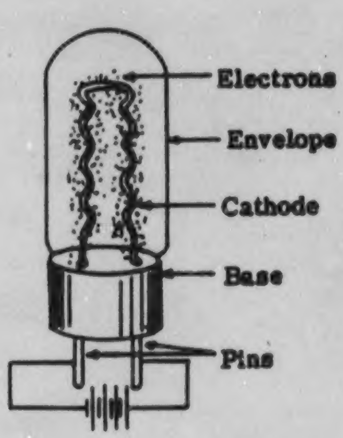


Figure 37. Tube Components

One of the most common ways of introducing electrons into the vacuum is by placing a conductor in the vacuum and heating it. This "giving off" of electrons by heating the conductor is called thermionic emission.

If a thin wire or filament is heated to a very high temperature inside a vacuum, many electrons will be driven off the surface or "emitted" from the conductor into the vacuum. This wire becomes an electron "emitter." As the temperature is increased (within certain limits) the number of electrons released from the filament will increase. These electrons emitted into the vacuum (space) form a negative charge around the "emitter." This charge is called a "space charge." The emitter is commonly called the cathode.

It is not necessary that the heating current always flow through the actual material that does the emitting. The heater can be electrically separated from the part that emits electrons. There are two types of cathodes in vacuum tubes. They are directly heated and indirectly heated. See figures 38 and 39.

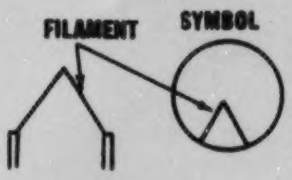


Figure 38. Directly Heated Cathode

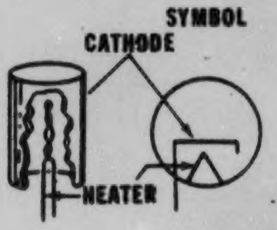


Figure 39. Indirectly Heated Cathode

Operation of the Diode Tube

A basic law of electricity states that like charges repel each other and unlike charges attract each other. Electrons emitted from the cathode of an electron tube are negative electrical charges. These charges may either be attracted to or repelled from the plate of a diode tube depending whether the plate is positively or negatively charged.

Figure 40 is a simple illustration of a diode circuit and its basic action. A battery has been connected between the plate and cathode so as to make the plate negative and the cathode positive. A high voltage power source must be used to help pull the electrons through the vacuum. With a voltage now applied to the heater, the cathode will emit electrons (thermionic emission). These electrons are strongly repelled from the negatively charged plate and tend to fill the space between the cathode and plate. Since none of the electrons actually reach the plate and the tube acts

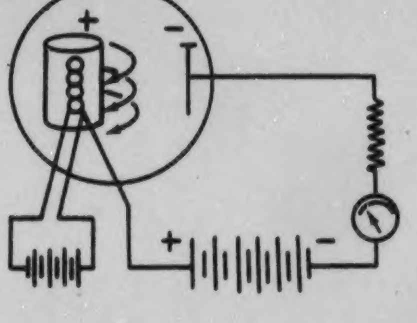


Figure 40. No Current when Plate is Negative

as an open circuit and the milliammeter connected externally between the cathode and plate indicates no current flow.

If the battery connections are reversed as shown in figure 41, the plate now becomes positive and the cathode negative. Again applying a heater voltage results in emission of electrons from the cathode. These electrons follow the magnetic lines of force and are literally yanked (pulled) to the positive plate (due to the high voltage power source) and strike the plate at a very high speed. Since moving electrons comprise an electrical current, the stream of electrons to the plate is an electrical current and is termed "Plate Current."

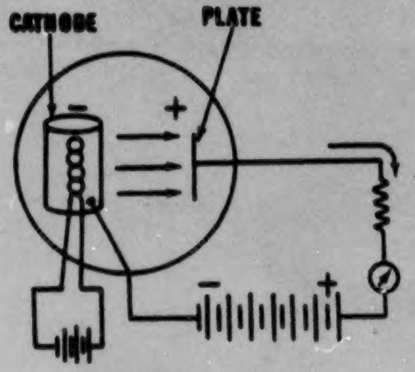


Figure 41. Current in a Diode with a Positive Plate

Upon reaching the plate the electron current continues to flow through the external circuit made up of a milliammeter, battery and connecting wires. The arriving electrons are absorbed into the positive terminal of the battery and an equal number of electrons flow out the negative terminal replacing the supply of electrons lost by thermionic emission.

The following conclusions may be drawn from figures 40 and 41:

1. Electrons flow (plate current) in the diode tube only when the plate is made positive.
2. No current can flow when the plate is negative.
3. Current flow within a diode tube is one-directional and takes place only from the cathode to the plate. Never from the plate to the cathode.
4. Because of its unidirectional characteristic a diode can be made to act as a switch or valve, automatically stopping or starting the plate current depending on whether the plate is positive or negative with respect to the cathode. This ability permits diode tubes to change alternating current to direct current, or as this is termed, to rectify.

RECTIFICATION. Rectification is the changing of alternating current into pulsating direct current by eliminating the negative half cycle or alternations of the ac voltage. An ideal rectifier can be thought of as a switch that closes a load circuit when the alternating current is positive and opens the circuit when the alternating current is negative. This is called unidirectional characteristic.

Half-wave rectification--diode rectifier. A diode is any electronic device consisting of two elements, one being an electron emitter (cathode) and the other an electron collector (plate or anode). Since a diode will permit current to flow only during the positive half cycles of the applied ac voltage, it is termed a half wave rectifier.

Figure 42 illustrates a half-wave rectifier circuit with its input and output waveforms. As you can see this is a very simple circuit.

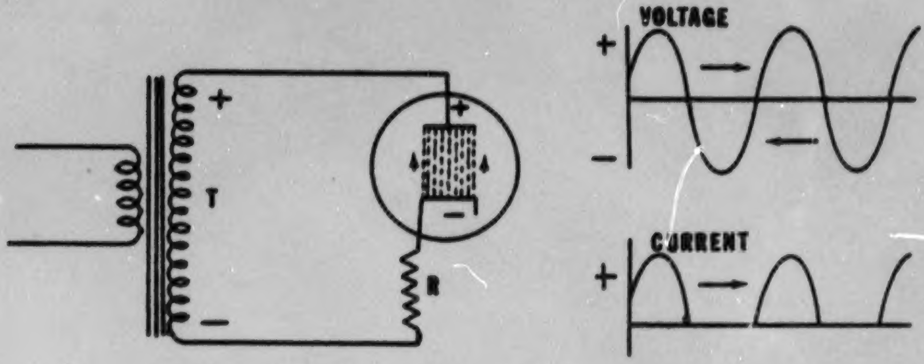


Figure 42. Rectification in a Diode Vacuum Tube

The ac supply voltage is applied through a transformer which is in series with the diode tube and the resistance load. Plate current flows through the tube every other half cycle or during the positive alternation of the input voltage and is blocked during the negative half cycle. The efficiency of the half-wave rectifier is very low and it is used only for applications requiring a small current drain.

Full-wave rectification--duodiode rectifier. Frequently the elements for two or more tubes are placed in one envelope. When the elements of two diodes are placed in one envelope, the tube is called a duodiode. See figure 43.

Both alternations of the ac cycle are used. If the plate at A is positive, electrons will flow as indicated by the solid arrows. The plate at B is negative so it will not conduct during the first alternation. During the second alternation the plate at B is positive. Electrons will flow as indicated by the arrows during the second alternation.

A center-tap transformer must be used to produce full-wave rectification. Figure 43 illustrates a center-tap multicoil transformer. The heater is supplied with low voltage. The two plates and load "R" are electrically connected to the center-tap portion of the transformer. The center-tap supplies electrons to the cathode. The two ends supply high voltage ac to the plates.

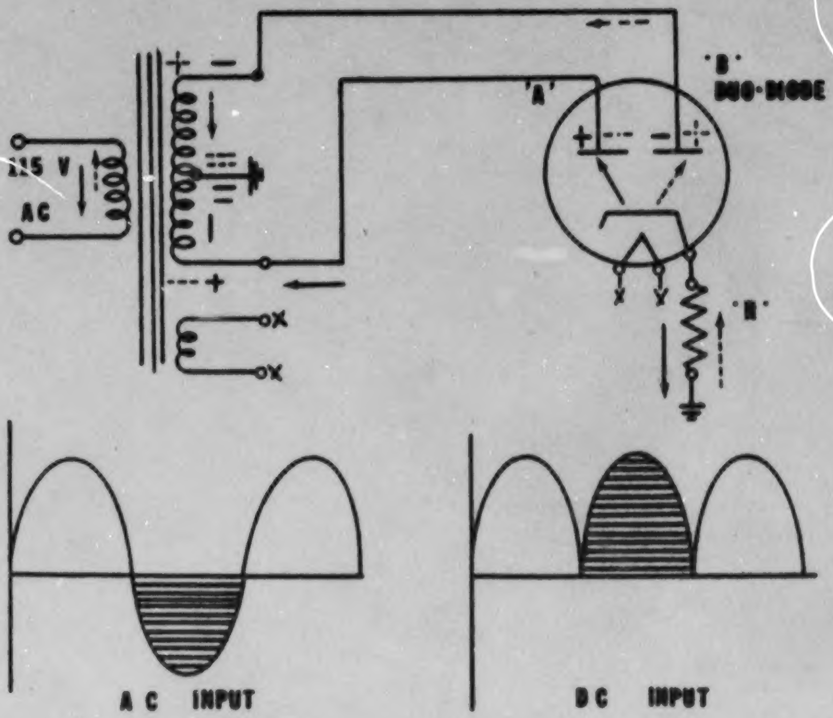


Figure 43. Full-Wave Rectifier

FILTER CIRCUIT. Although the rectifier circuits deliver an output voltage that always has the same polarity, this voltage is not suitable for most dc electronic equipment, because of the pulsations or ripples. These pulsations must be smoothed out before this current can be applied to various electronic circuits.

Figure 44 illustrates a typical filter circuit. The filtering action of the coil and capacitors depend on basic electrical principles.

A capacitor opposes any change in the voltage applied across its terminals storing up energy when the voltage tends to rise (goes positive) and converts this stored energy back into current flow when the voltage across its terminals tends to fall (goes negative). Thus, some of the energy of the rectifier output pulsations is stored in the electrical field of the capacitor and the capacitor discharges between current pulses. The ripple in the output is reduced.

An inductor coil (choke) opposes any change in the magnitude of current flowing through it by storing energy in a magnetic field when the current through it tends to increase and by taking energy away from the field to maintain current flow when the current through the inductor tends to decrease.

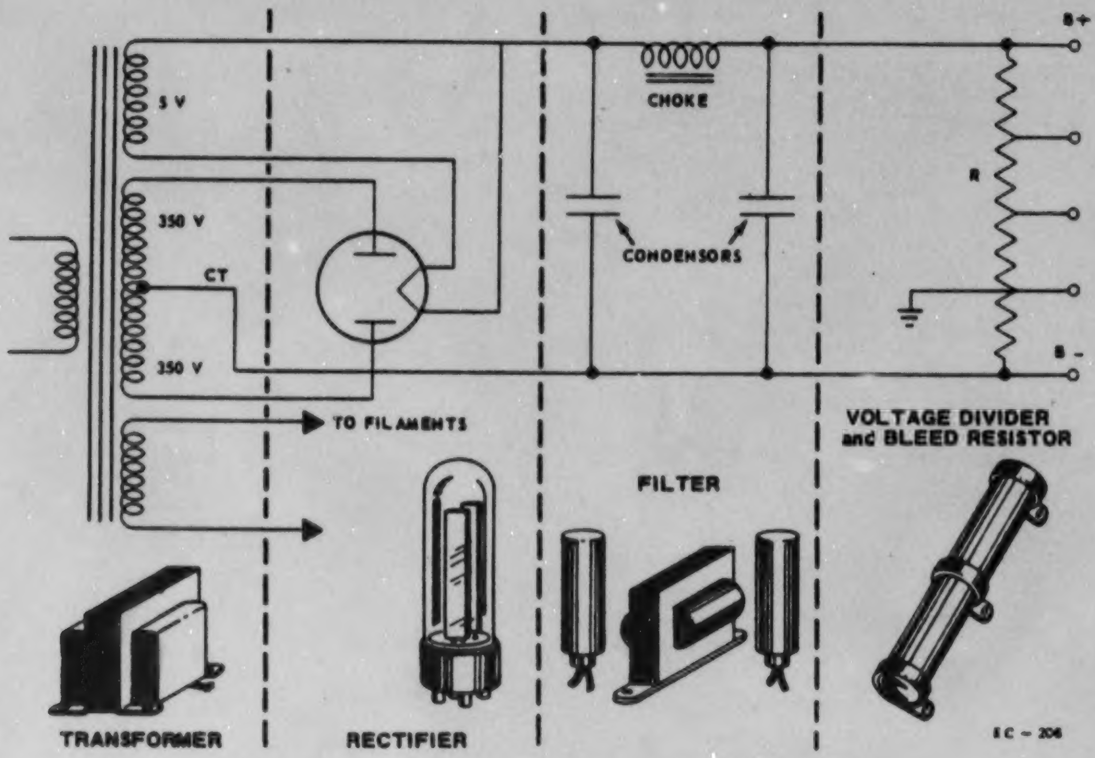

B+
5 V
CHOKE
R
350 V
CT
CONDENSORS
350 V
B -
TO FILAMENTS
VOLTAGE DIVIDER and BLEED RESISTOR
FILTER
TRANSFORMER
RECTIFIER
EC - 206

Figure 44. Full-Wave Power Supply

VOLTAGE DIVIDER. The voltage divider is a resistor connected across the output terminals of the power supply. Its functions in the system are as follows:

1. Its main purpose is to place a minimum load across the rectifier during the time when the tubes are heating up and not drawing any current. Without this there would be an initial high voltage surge when the rectifier is turned on.

2. The resistor discharges the capacitors after the rectifier has been turned off and so prevents shocks.

3. The resistor is provided with taps for supplying voltages of different amounts to various tube electrodes or electronic equipment.

Operation of the Triode Tube

In 1907 Lee DeForest added a third element to a tube and increased its application hundreds of times. When the third electrode (grid) is placed between the cathode and plate, the tube is called a triode. Its ability to amplify tiny signals and its ability to control current flow of electrons has led to many developments in the world of electronics.

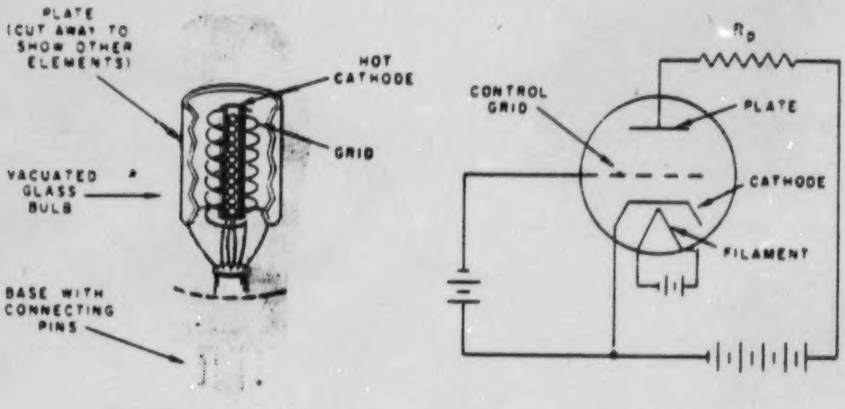
This third electrode or grid will be referred to as a Control Grid. It is a mesh or spiral of fine wire placed close to and around the cathode. It is an electrode that contains openings through which "free" electrons can flow. The purpose of this grid is to CONTROL the flow of electrons to the plate and not to attract them. The grid itself does not present an obstacle to the flow of electrons, but a negative potential on the grid has an important controlling effect on the number of electrons reaching the plate.

Since the control grid is physically closer to the cathode than the plate, a very small voltage change on the grid will have the same effect on the plate as a large change in plate voltage.

Methods of varying plate current, in their order of efficiency:

1. Grid potential. (Varying the small grid voltage.)
2. Plate potential. (Varying the large plate voltage.)
3. Heater potential. (Varying the small voltage to the filament.)

Figure 45 illustrates a triode tube and its electrical symbol.



TRIODE CUT AWAY

ELECTRICAL SYMBOL & CIRCUIT

Figure 45. Triode Tube

Grid Bias. The difference in potential or dc voltage between the control grid and the cathode.

The purpose of this grid bias is to place the tube in the desired operating condition as determined by its purpose in the circuit.

The difference in potential will allow more or less electrons to flow from the cathode to the plate. The more negative the bias, the less electrons will flow; the more positive the bias, the more electrons will flow.

By varying the amount of electrons flowing through the tube, the triode amplifies and controls current flow.

SOLID STATE SEMICONDUCTORS

In the next few years, we in the Air Force will see great strides forward in the field of solid state devices as applied to refrigeration and air-conditioning control systems.

This section of your study guide will familiarize you with some of the many types of solid state devices, their advantages, operational principles, and various applications in the control systems.

The advantages of solid state controls are as follows:

1. Long life
2. Reliability
3. Speed of response
4. Smaller size
5. Ruggedness
6. Less heat generated
7. Reduced cost of operation
8. High resistance to extreme environmental changes

The term "solid state" is applied to semiconducting devices, because they are "solid." They are made of crystalline substances, so they do not contain filaments. glass enclosures, or rare gases, as tubes do.

Another term we should define at this time is "semiconductor." You know the characteristics of conductors which readily allow current to flow through them and with insulators which block all current flow. Semiconductors however have some of the characteristics of both conductors and insulators. They do allow current to flow through them, but normally have very high resistance.

There are two basic types of materials used to construct solid state electronic devices. They are germanium and silicone. These materials have a crystalline structure. They are electrically stable materials. That is, they have as many electrons as they do protons within their atomic structure. Due to this electrical stability. they are not suitable by themselves to do the job of rectifying and amplifying.

In their natural state, germanium and silicone have four valence electrons; that is, there are four electrons in the outermost orbit from the nucleus as indicated in figure 46 below.

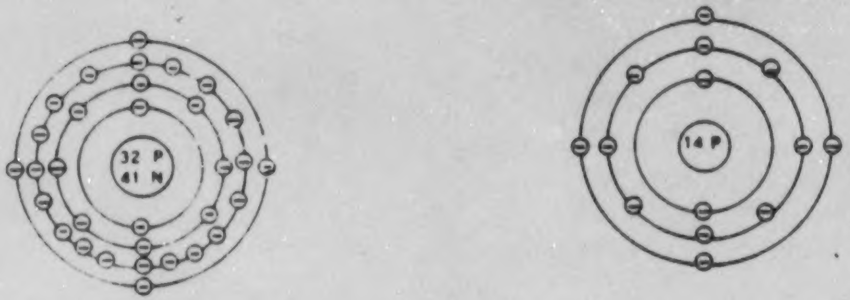


Figure 46.

The atoms of silicone and germanium bond together to form what is called electron pair bonds, see figure 47.

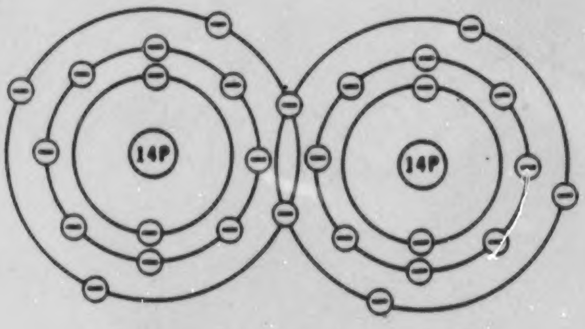


Figure 47. Electron Pair Bonding of a Silicone Atom

This bonding takes place as a result of chemical instability within the atom. This joining together or bonding is also known as "covalent bonding." When atoms bond together in this manner, a lattice structure is formed.

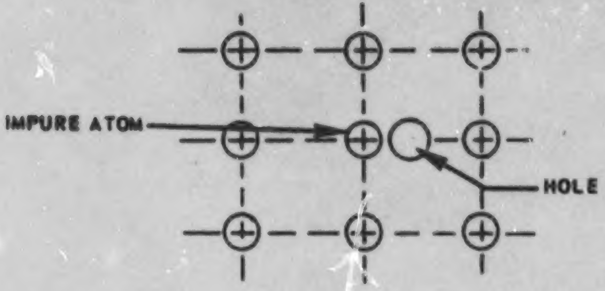


Figure 50. P-Type Semiconductor Lattice

In this structure, there is an electron missing in the lattice. When this condition exists, we say there is a "hole" in the material. This condition causes the electrical balance of the material to be upset. The material now has a positive charge. This type of material is designated with a "P" meaning positive, see figure 50A.

$\boxed{P}$ Electrically unstable material with a positive charge.
Material has a deficiency of electrons.

Figure 50A. P-Type Material Symbol

The other type material that can be made when an impurity with one extra electron is added to the semiconducting material is the N-Type. The impurity added is called a "donor," because it gives or donates one electron to the lattice structure. The type material that is formed is called "N" meaning negative. The lattice structure that is formed from this combination is illustrated by figure 51.

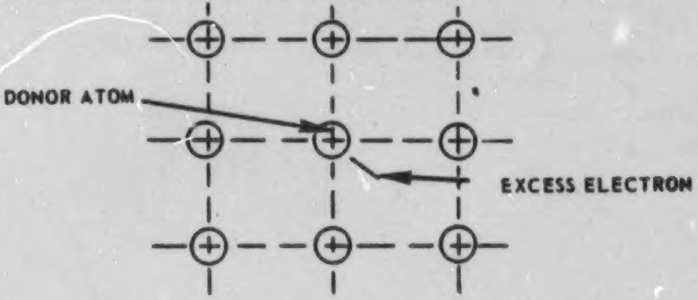


Figure 51. N-Type Material Lattice

This type material then has a negative charge. The symbol for this type material is shown in figure 51A.

$\boxed{N}$ Electrically unstable material with a negative charge.
Material has an excess of electrons.

Figure 51A. N-Type Material Symbol

Now that you know what "P" and "N" type semiconducting material is. We can proceed to a discussion of the simplest of all semiconducting devices. the junction diode.

JUNCTION DIODE

The junction diode consists of two dissimilar blocks of semiconducting material joined together with wire leads attached, see figure 52.

When molten dissimilar semiconducting materials are joined together in this manner, a junction is formed where the two types of material come together. The reaction that occurs when these materials are joined is what makes them usable in electronic circuits.

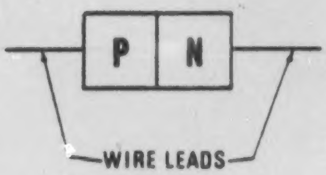


Figure 52. Junction Diode

One would think that when a piece of positively charged material and a piece of negatively charged material are brought together in this manner that their charges would neutralize. This is not the case, however, at the junction some of these positively charged atoms do take the extra electron from the negatively charged atoms. When this happens the atoms involved do become electrically neutral. When this takes place the neutral atoms tend to remain at the junction. As a result a neutral barrier or depletion region is formed at the junction, which prevents further combining taking place, see figure 53.

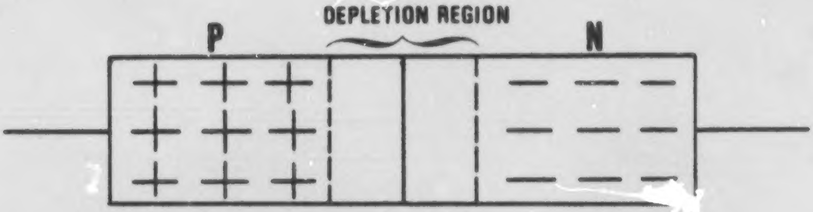


Figure 53. Junction Diode Depletion Region

As a result of the depletion region forming within the crystal a peculiar phenomenon takes place when an external source of electrical energy is attached to the wire leads. The external source of energy is called biasing.

When a battery is connected as shown in figure 54, no current will flow across the junction.

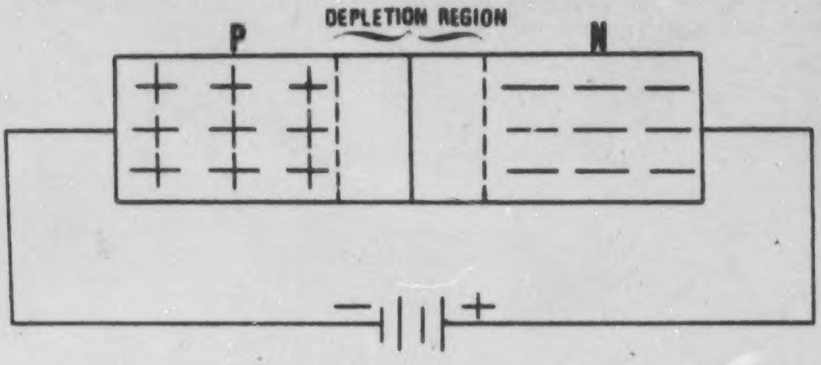


Figure 54. Junction Diode Reverse Bias

The lack of current flow in figure 54 is due to the fact that the negative terminal of the battery attracts the positive ions from the P-type material and the positive terminal attracts the negative ions of the N-type material toward its battery terminal. This causes the neutral or depletion region to grow larger. Thus, no current can flow due to the increase in size of the depletion region.

If, however, we connect the battery as shown in figure 55, current will flow.

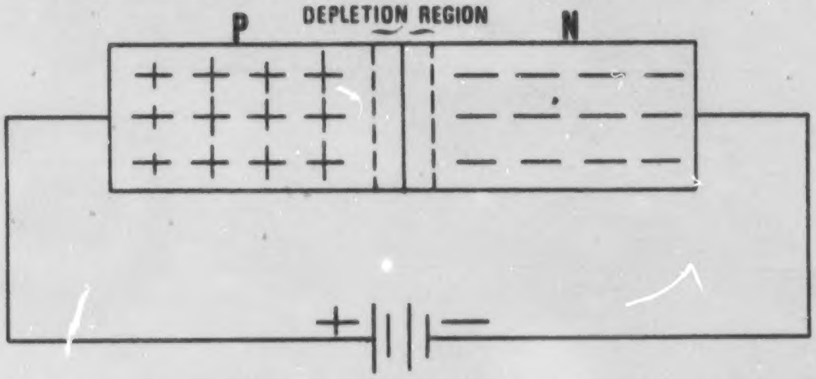


Figure 55. Junction Diode Forward Bias

The flow of current is due to the positive terminal repelling the positive ions in the P-type material toward the junction and the negative terminal repelling the negative ions in the N-type material toward the junction. This causes the depletion region to become very small. When the depletion region becomes small, the negative ions will again start to combine with the positive ions. When this happens, electrons will flow from the N-type material into the P-type material and on to the positive terminal of the battery. Thus when it is forward biased, we have a current flow from negative to positive through the junction diode.

The lead attached to the P-type material is called the collector and the lead attached to the N-type material is called the emitter. see figure 56.

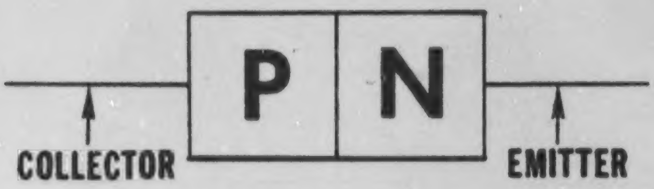

P
N
COLLECTOR
EMITTER

Figure 56. Junction Diode

The symbol for the junction diode is shown in figure 57.

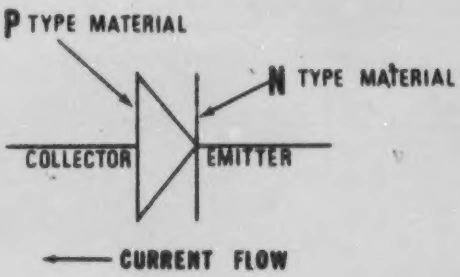
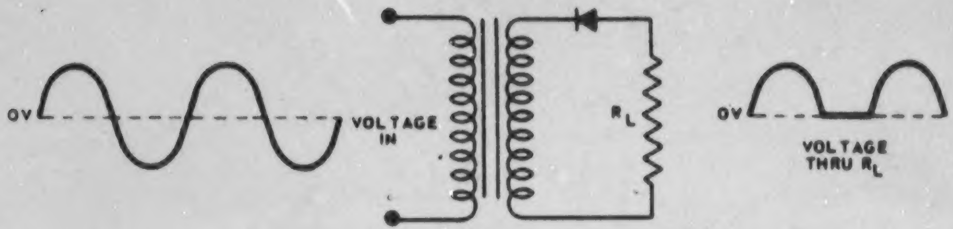

P TYPE MATERIAL
N TYPE MATERIAL
COLLECTOR
EMITTER
CURRENT FLOW

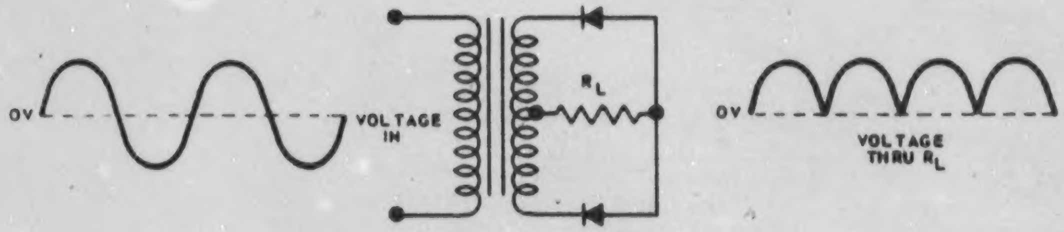
Figure 57. Junction Diode Symbol

By this time you know that the junction diode will only allow current to flow in one direction. As you recall the vacuum tube diode does the same thing. They are used to the same goal: rectifying alternating current.

Figure 58 illustrates the use of the solid state diode as a rectifier.


OV
VOLTAGE IN
R_L
OV
VOLTAGE THRU R_L

HALF WAVE RECTIFIER


OV
VOLTAGE IN
R_L
OV
VOLTAGE THRU R_L

FULL WAVE RECTIFIER

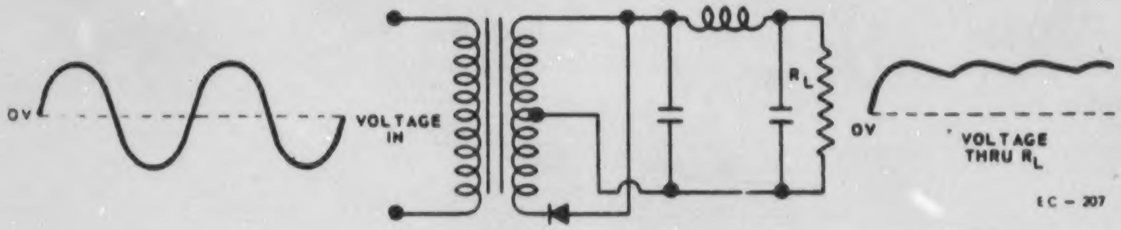

OV
VOLTAGE IN
R_L
OV
VOLTAGE THRU R_L
EC – 207

Figure 58. Full-Wave Rectifier with Filter

The solid state diode like the vacuum diode cannot amplify. As you recall, we had to add a third electrode to the diode tube called the grid, before it could be used as an amplifier. The same is true with the solid state diode. We must add a third element called the base before we can use the device as an amplifier.

SOLID STATE TRIODES

The solid state triode or transistor, as it is called, can be found in two basic types. These are the NPN and PNP types. Refer to figure 59 for a block diagram and symbol for these transistors.

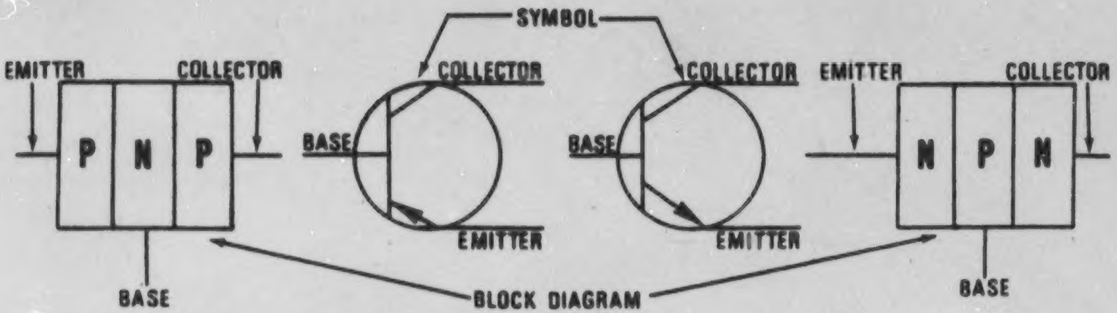

SYMBOL
EMITTER
COLLECTOR
P
N
P
BASE
COLLECTOR
BASE
EMITTER
COLLECTOR
BASE
EMITTER
EMITTER
COLLECTOR
N
P
N
BASE
BLOCK DIAGRAM

Figure 59. Transistor Symbols

To identify a PNP or NPN transistor you must look at the direction the arrow is pointing on the symbol. The PNP transistor has the arrow pointing toward the base, while the NPN arrow points away from the base. This is the only method of identifying them on a schematic. The majority of the current flow through a transistor is from the collector to the emitter, or emitter to the collector and is opposite to the direction indicated by the arrow.

As with tubes, transistors must be biased properly before they will operate. Figure 60 illustrates the basic method of biasing a common emitter circuit for both an NPN and PNP transistor.

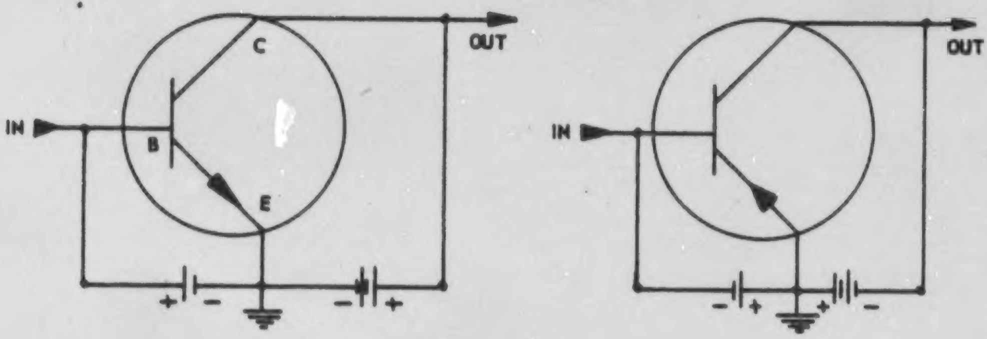

C
OUT
IN
B
E
+
−
−
+
OUT
IN
−
+
+
−

Figure 60. Proper Bias of the Grounded Emitter Amplifier

This method of connecting a transisor into a circuit is the one most commonly used. It also has the highest power gain of any transistor circuit. There are two other basic methods of connecting transistors, they are, the grounded base and grounded collector circuits.

Transistors perform the same tasks as tubes in the electronic circuit, but they do the job much better.

SUMMARY

In general, solid state devices have many advantages over tubes. Solid state devices are neither conductors or insulators. They are semiconductors, because they display some of the characteristics of both. Semiconductors are made by doping a germanium or silicone crystal with an impurity which makes them either positively or negatively charged. The two basic types of material derived from this process are called N- or P-type material.

By combining these two basic types of material in various ways, solid state rectifiers and amplifiers are made.

BASIC ELECTRICAL CONTROL CIRCUIT

Figure 61 illustrates a block diagram of the components of an electronic circuit. Temperature changes at the thermostat will unbalance the bridge circ The voltage change which results from this unbalance is increased by an ampli to energize the regulatory element (switching relay). The activated relays will gize one or more final control elements (valves or dampers).

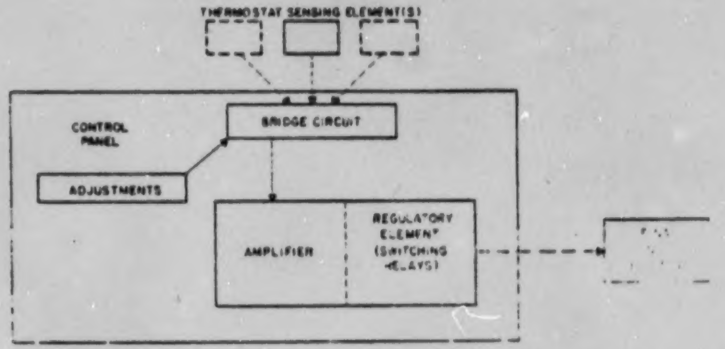

THERMOSTAT SENSING ELEMENT(S)
CONTROL PANEL
BRIDGE CIRCUIT
ADJUSTMENTS
AMPLIFIER
REGULATORY ELEMENT (SWITCHING RELAYS)

Figure 61. Basic Electronic Control Circuit

The sensing elements, bridge circuits, amplifier, regulatory elements and the final control element will now be discussed in a sequence of operation.

Sensing Elements

The sensing element of an electronic thermostat is a coil of fine wire wound on a bobbin, figure 62. The type of wire most often used is Balco. Resistance of this type of wire varies directly with temperature and at 74°F it will have 1000 ohms resistance. A temperature change of 1°F changes the resistance by 2.2 ohms.

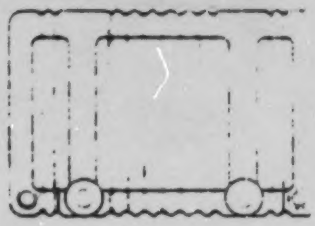


Figure 62. Sensing Element of an Electronic Space Thermostat

The sensing element of the humidity controller is a Gold Leaf Grid embossed on a plastic base and covered with a special salt (lithium chloride). Figure 63 illustrates a typical humidity element. You will note that the gold foil forms two grids. The salt forms a conductive path between these grids. The electrical resistance in this circuit measured in thousandths of an ohm changes as the chemical film absorbs or releases moisture with each change in relative humidity of the surrounding air.

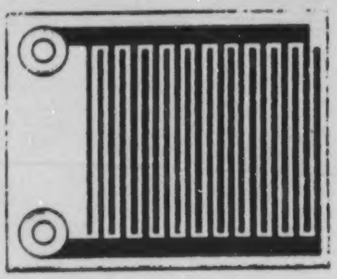


Figure 63. Sensing Element of a Space Humidity Controller

Bridge Circuits

The brain of most electronic controls is a modified Wheatstone bridge. To understand the bridge circuit we will review the operation of a variable resistor (potentiometer) first.

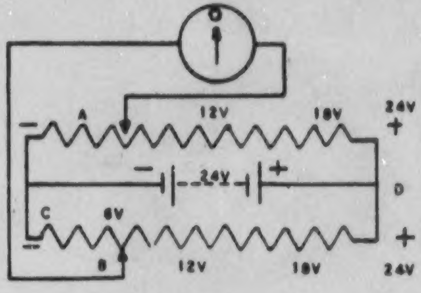
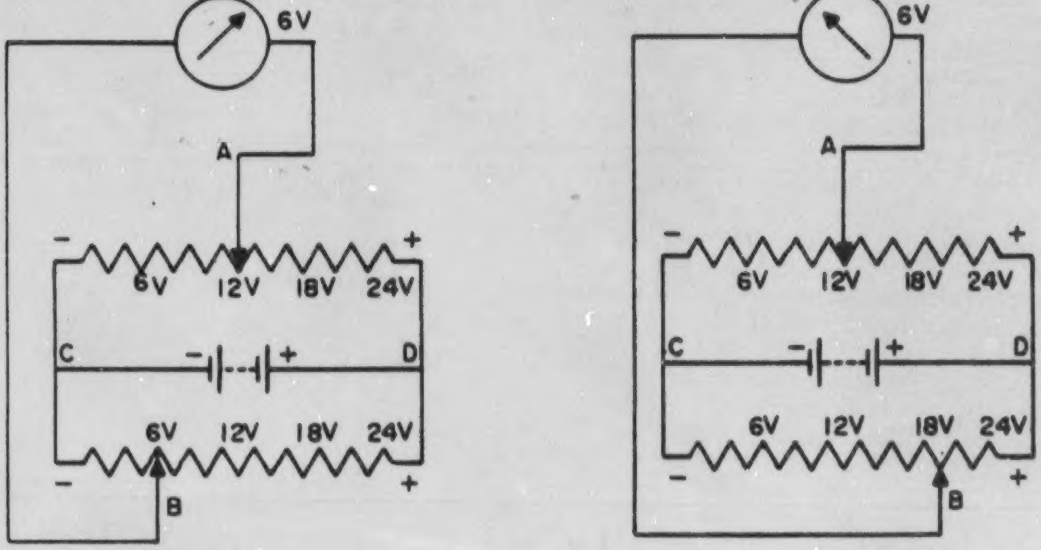


Figure 64. Simple Bridge

Figure 64 shows two resistors connected in parallel with their wipers connected to a voltmeter. Since the two resistors are connected in parallel, the voltage applied by the battery is equally distributed along each of the two pots. Such a combination of pots is called a bridge. Notice that each wiper is at a positive potential with respect to point C of 6 volts and consequently the voltmeter indication is zero volts. Since no current flows between the wipers, the bridge is said to be balanced. If wiper A is moved to the center of the top pot, figure 65, it would take off 12 volts; however, wiper B is taking off 6 volts and the meter would read 6 volts (the difference between 6 and 12). Electrons would flow from B (negative) through the meter to A (positive in respect to B). The meter would be deflected to the right 6V so we can say the bridge is unbalanced to the right. Moving wiper B toward the positive potential and A toward negative will cause the bridge to unbalance to the left because current would flow from A to B deflecting the meter to the left. This is demonstrated in figure 65b.



a
Unbalanced to Right

b
Unbalanced to Left

Figure 65

Figure 66 shows a Wheatstone bridge. The basic operation is the same as the common bridge shown in figure 65 but it uses only one variable resistor.

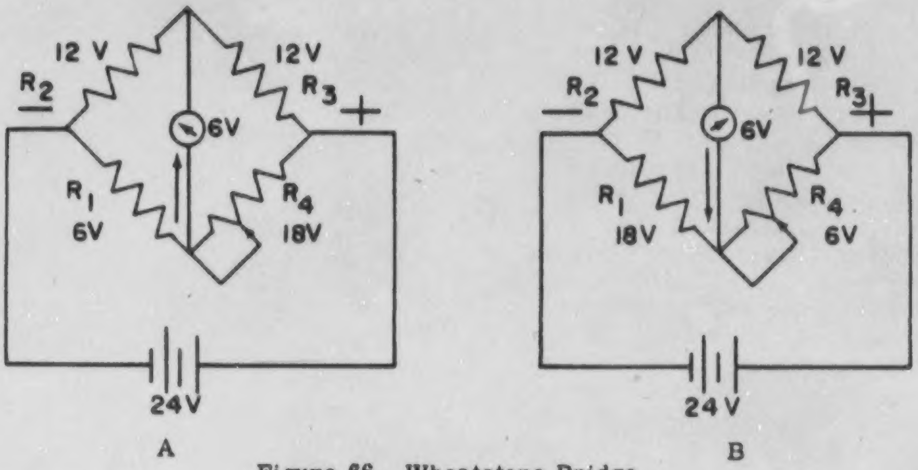


Figure 66. Wheatstone Bridge

The variable resistor has a higher resistance value than the three fixed resistors. When the variable resistor is centered, it has the same value as the fixed resistors and the bridge is in balance for no voltage is indicated by the meter. Each resistor drops 12V. Figure 66A shows R4 unbalanced to the left. Due to its higher resistance it now drops 18 of the applied volts and the remaining 6V are dropped by R_1. The difference between 6 and 12 or 12 and 18 is across the meter (6V). Since current flows from negative to positive, the flow through the meter is toward the top of the page. Figure 66B shows R4 unbalanced to the right. This drops its value, causing most of the applied voltage to be dropped across R_1 (18V). The difference between 12 and 18 (6V) is across the meter but in this case flowing toward the bottom of the page (- to +).

The Wheatstone bridge can be used on ac or dc but if ac is used, it requires a phase detector discussed later in this guide.

The ac Wheatstone bridge is used with most electronic controls. Note that in figure 67, the dc power source has been replaced with a transformer and the voltmeter has been replaced with an amplifier. The amplifier simply builds up the small signal from the bridge to operate a relay.

T_1 (thermostat) now takes the place of R_3. The sensing element is a piece of Balco wire that changes in value as the temperature changes. An increase in temperature will cause a proportional increase in resistance. As you will note in figure 67, at set point of 74°F, the bridge is in balance. The voltage at points C and D is the same (7.5V), and the amplifier will keep the final control element in its present position until we have a temperature change. Now let's assume the control point changes.

When the temperature at T_1 is lower than set point, its resistance is less than 1,000 ohms. This causes more than 7.5 volts to be dropped by R_2. This means that point C has a higher voltage than point D. The amplifier will then take the necessary action to correct the control point.

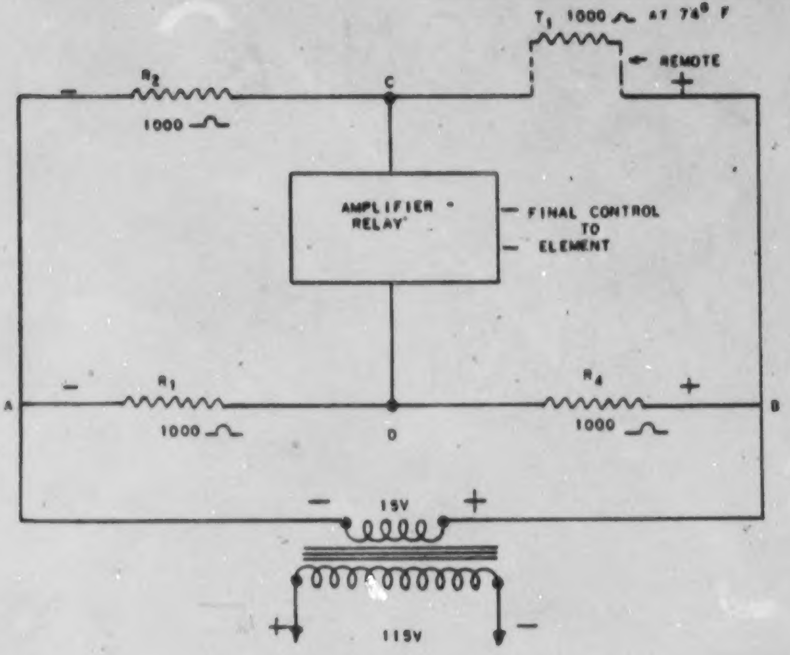


Figure 67. AC Wheatstone Bridge

When the temperature at T_1 is higher than set point, its resistance is more than 1,000 ohms, causing less than 7.5 volts to be dropped across R_2. This means that point C has a lower voltage than point D. The amplifier will once again take the necessary corrective action.

The resistance of T_1 changes 2.2 ohms for each degree of temperature change. This will cause only .0085 volt change between points C and D. For this reason, to check the bridge circuit, one will have to use an electronic meter usually called a VTVM for vacuum tube voltmeter. The vacuum tube voltmeter will usually have an ohms scale, as well as ac and dc voltage scales.

Discriminator Circuit

See figure 68 for a typical discriminator (phase detector) circuit. The bridge originates the signal voltage, the amplifier increases the strength of this voltage and the discriminator discriminates this signal. That is, it prepares the power to the motor in such a way that it will cause the shaft to rotate in the right direction to correct the condition, which caused the signal to be introduced into the bridge.

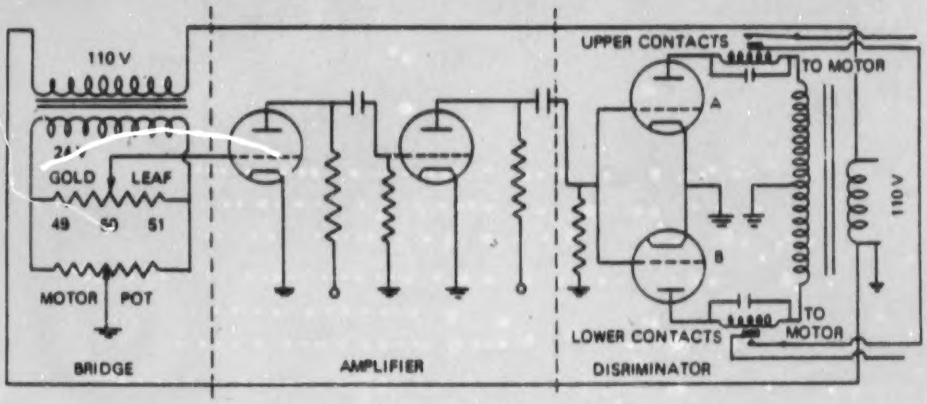

110 V
24 V
GOLD LEAF
49 50 51
MOTOR POT
BRIDGE
AMPLIFIER
UPPER CONTACTS
TO MOTOR
A
B
110 V
TO MOTOR
LOWER CONTACTS
DISRIMINATOR

Figure 68. Schematic of Bridge, Amplifier, and Discriminator (Phase Detector) Circuit

For the sake of simplicity, many of the resistors and condensers are not shown in these diagrams.

The conditions when the discriminator tubes will conduct are

1. When plate is positive.
2. When signal on grid is positive. That is, on the positive alternation.

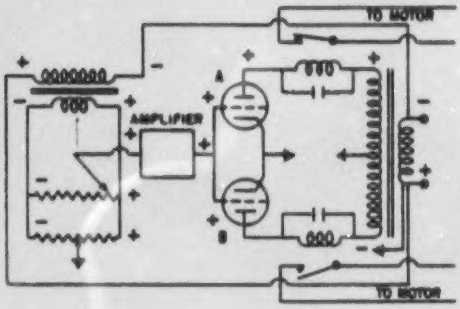

TO MOTOR
AMPLIFIER
A
B
TO MOTOR

Figure 69. Tube A Conducts

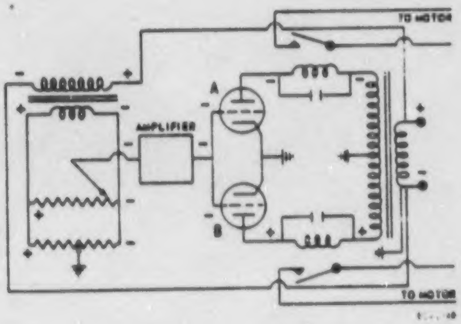

TO MOTOR
AMPLIFIER
A
B
TO MOTOR

Figure 70. Neither Tube Conducts

On the other alternation of this cycle, see figure 70. Tube "B" has a positive plate, but since the signal is on the negative alternation, neither tube can conduct.

With bridge unbalanced to the right, the only tube which will conduct is tube A.

Now going to figure 71B, the bridge is unbalanced to the left, and the negative alternation of signal is applied to the grids of the discriminator tubes so neither tube can conduct.

On the next alternation, with bridge still unbalanced to the left, see figure 71A, tube B meets the conditions necessary so it will conduct. Tube A has a negative plate and cannot conduct.

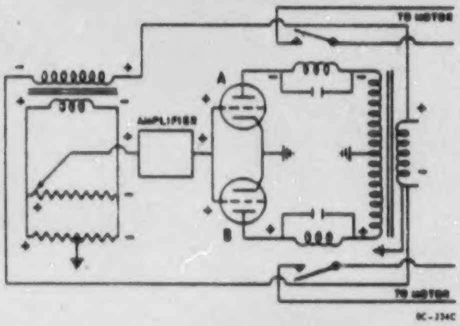


Figure 71A. Tube B Conducts

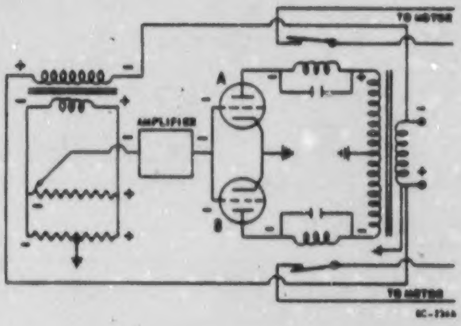


Figure 71B. Neither Tube Conducts

With the bridge unbalanced to right, one tube conducts, and with the bridge unbalanced to the left, the other tube conducts.

Figure 72 shows the phase relations of the line voltage, the voltage applied to tube A and the voltage applied to tube B. The line voltage will be used as reference voltage. Voltage applied to tube A is 180 degrees out of phase with line voltage. Voltage applied to tube B is in phase with line voltage, see figures 68, 69, 70, and 71.

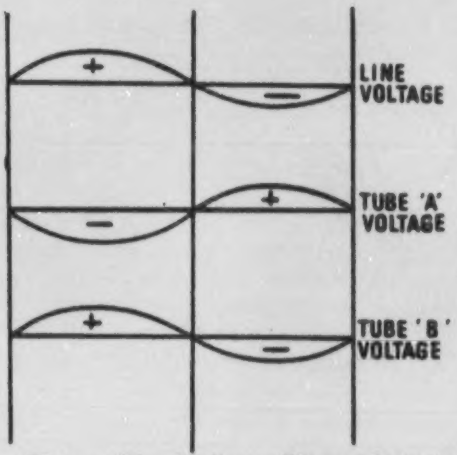


Figure 72. Voltage Phase Relations

Modulating Control

For modulating control, figure 73, a modulating motor is used with a balancing potentiometer. The balancing potentiometer is wired in series with the thermostat resistor. Its purpose is to bring the bridge back into balance when a deviation occurs. Assuming a rise in temperature at T_1 and the polarity as shown by the solid symbols (±), point C will be negative. Neither of the discriminator tubes will conduct as the control grids of both are negative beyond cutoff bias. During the next alternation (dotted symbols - - -) when the signal is positive, C_6 will charge and relay 2 will energize, causing the motor to run counterclockwise. This moves the wiper of the balancing potentiometer to the right, adding resistance to R_1 and removing resistance from T_1 until no signal is applied to the amplifier. Cutoff bias is reached on the control grids of the discriminators, capacitor C_5 discharges, relay 2 deenergizes, and the motor stops in its new position.

Figure 74 shows a decrease in temperature at T_1 causes a 180 degree phase shift from the bridge. This places the grid of discriminator tube No. 1 positive at the same time as the plate. Relay 1 energizes and the motor runs clockwise until the bridge is once again balanced.

For control of relative humidity the thermostat is replaced by a gold leaf humidistat. The principle of operation is the same; however, one must remember that increasing the moisture on a gold leaf causes the resistance to decrease.

Since these vacuum tubes conduct on only one alternation of each cycle, a panel switch coil will receive power to operate on only one alternation. Enough magnetism is developed, however, to maintain the contacts in a closed position without chattering.

Figure 75 shows a partial wiring diagram of an electronic humidity control. When the space humidity increases to 51 percent, the bridge is unbalanced to the right and tube A conducts. The upper switch on the electronic panel closes. Power is now available to the motor.

Current from the 24V transformer flows through the upper switch and through the limit switch. Because current leads voltage in a capacitive circuit and ac apparently goes through capacitors, current will follow the arrows as indicated in figure 75.

On the next alternation when the transformer polarity reverses, current will again go through the clockwise stator windings. Whenever the upper switch is closed, that is, when tube A conducts, the motor will rotate clockwise, this closes a steam humidifying valve and at the same time balances the bridge in a new position. By controlling the steam valve in this manner, the space humidity can be maintained near the set point.

When the bridge is unbalanced to the left, that is, when the humidity decreases, tube B conducts and starts current flow through the counterclockwise stator windings, opening the steam humidifying valve.

Temperature and pressure may be controlled electronically by substituting temperature or pressure sensing elements for the gold leaf sensing element.

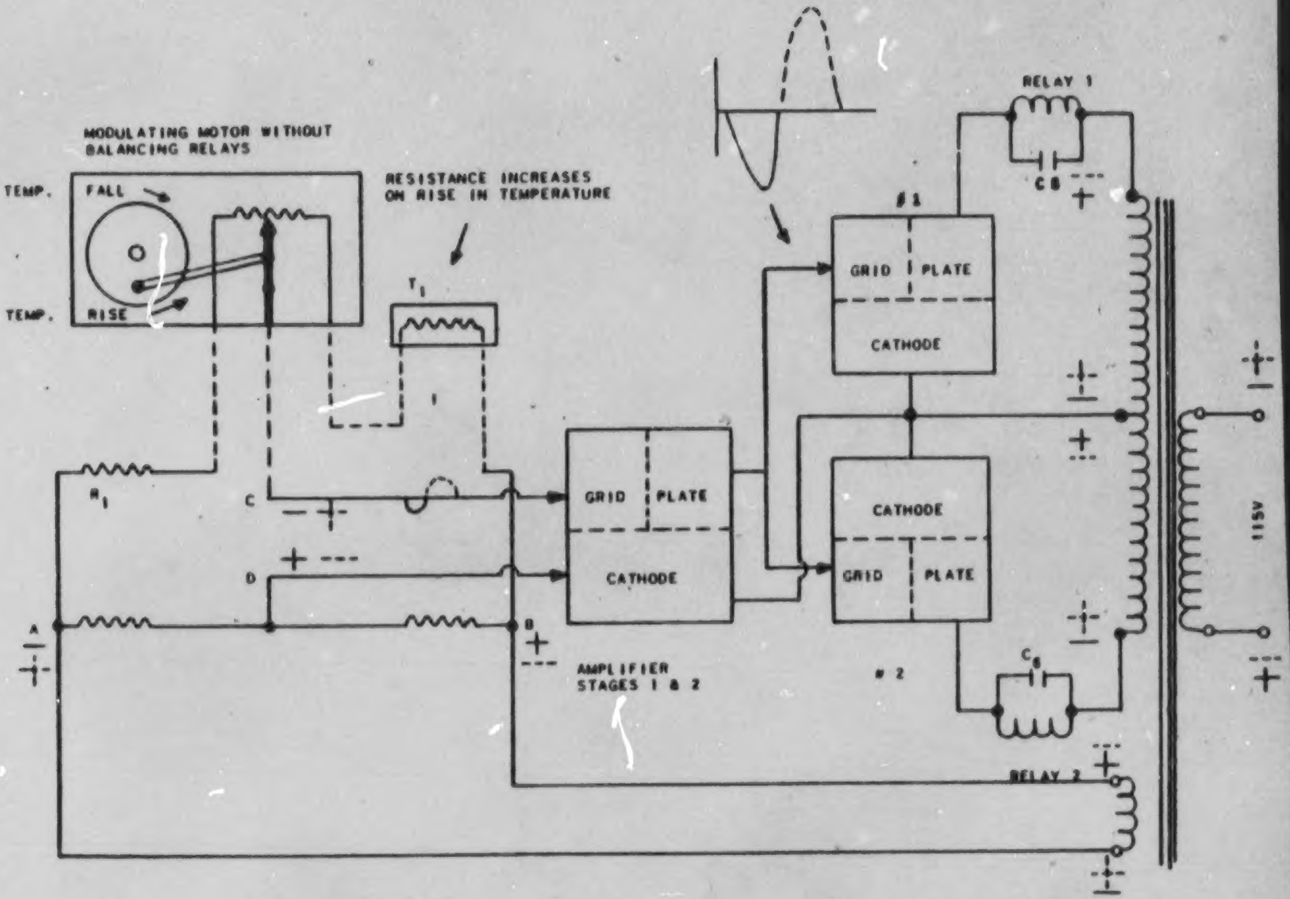

MODULATING MOTOR WITHOUT BALANCING RELAYS
TEMP.
FALL
TEMP.
RISE
RESISTANCE INCREASES ON RISE IN TEMPERATURE
T1
R1
C
D
A
B
GRID
PLATE
CATHODE
AMPLIFIER STAGES 1 & 2
#1
GRID
PLATE
CATHODE
CATHODE
GRID
PLATE
#2
RELAY 1
C8
C6
RELAY 2
115V

Figure 73A. Modulating Control

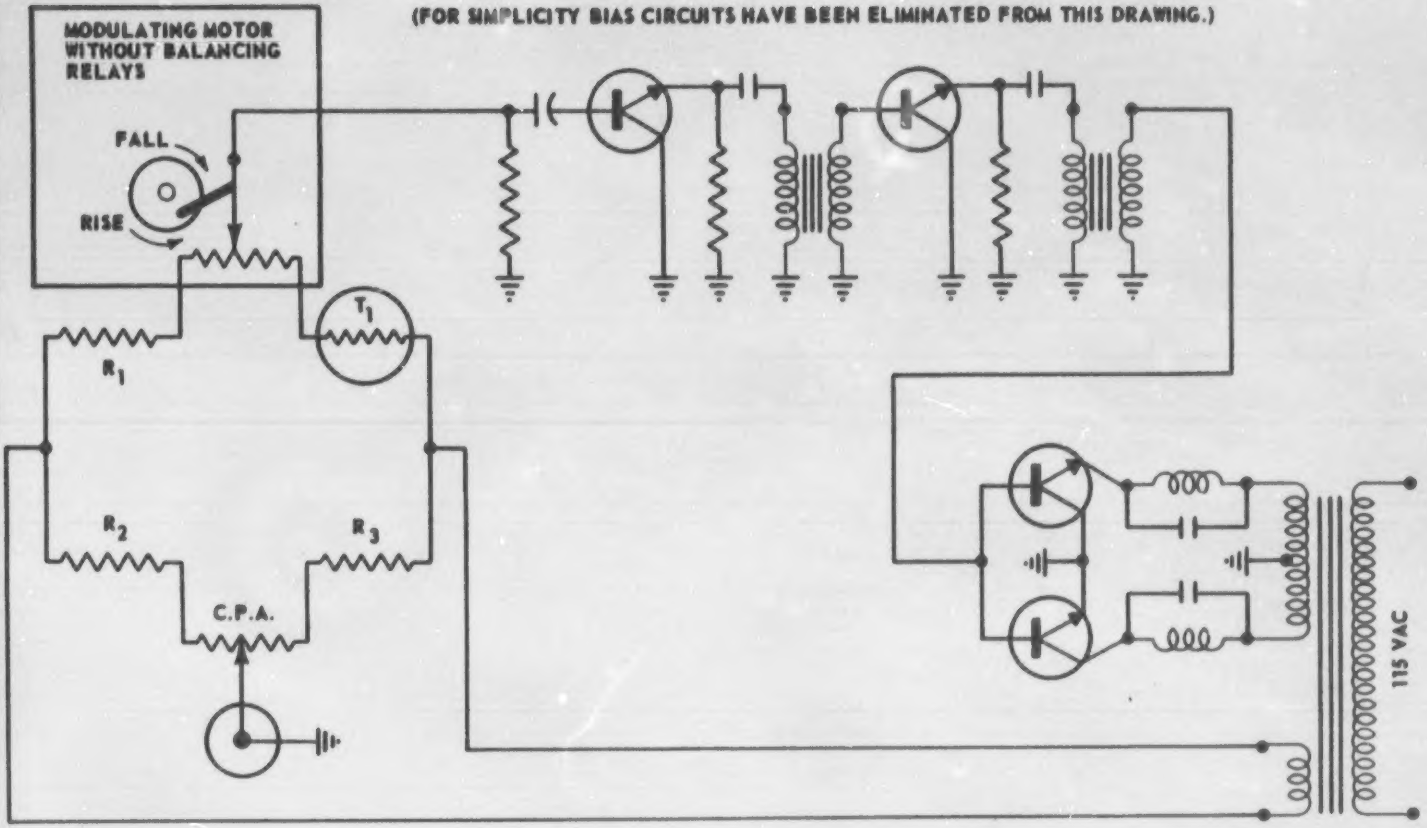

(FOR SIMPLICITY BIAS CIRCUITS HAVE BEEN ELIMINATED FROM THIS DRAWING.)
MODULATING MOTOR WITHOUT BALANCING RELAYS
FALL
RISE
T1
R1
R2
R3
C.P.A.
115 VAC

Figure 73B. Modulating Electronic Control Using Transistors

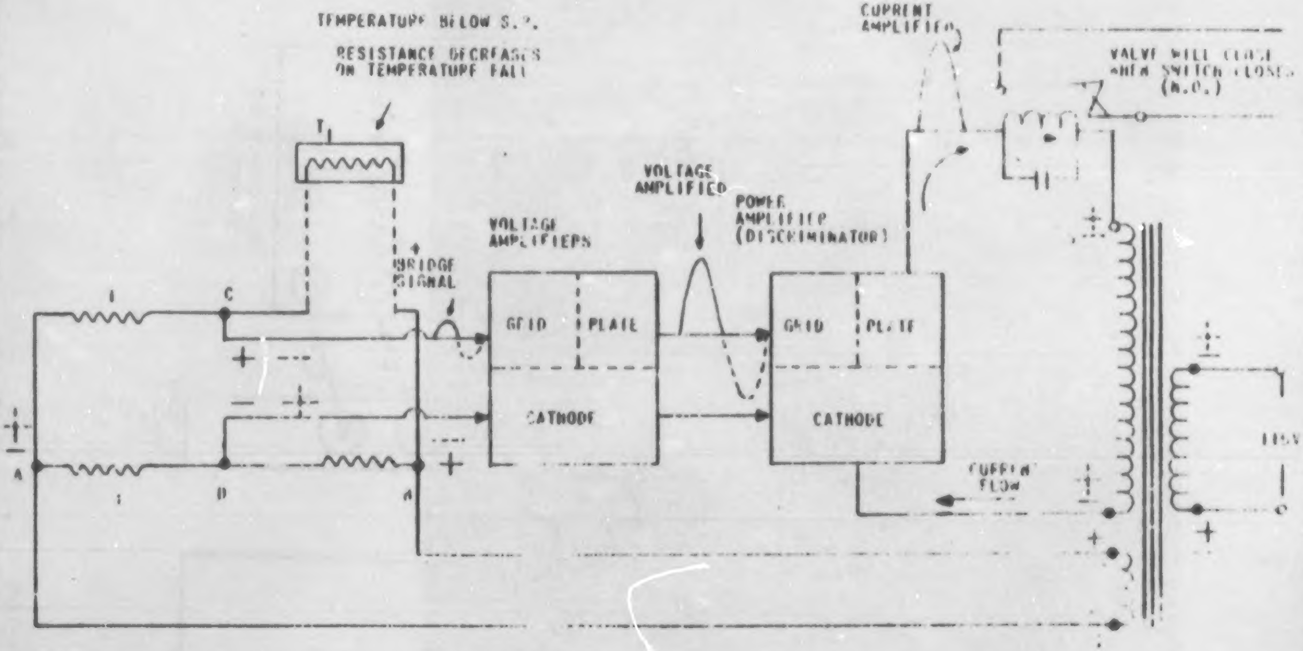

TEMPERATURE BELOW S.P.
RESISTANCE DECREASES ON TEMPERATURE FALL
T1
VOLTAGE AMPLIFIED
CURRENT AMPLIFIED
VALVE WILL CLOSE WHEN SWITCH CLOSES (N.O.)
VOLTAGE AMPLIFIERS
POWER AMPLIFIER (DISCRIMINATOR)
+ BRIDGE SIGNAL
GRID
PLATE
CATHODE
CURRENT FLOW
115V
A
B
C
D
+
−

Figure 74. Two-Position Summer Control (Cooling)

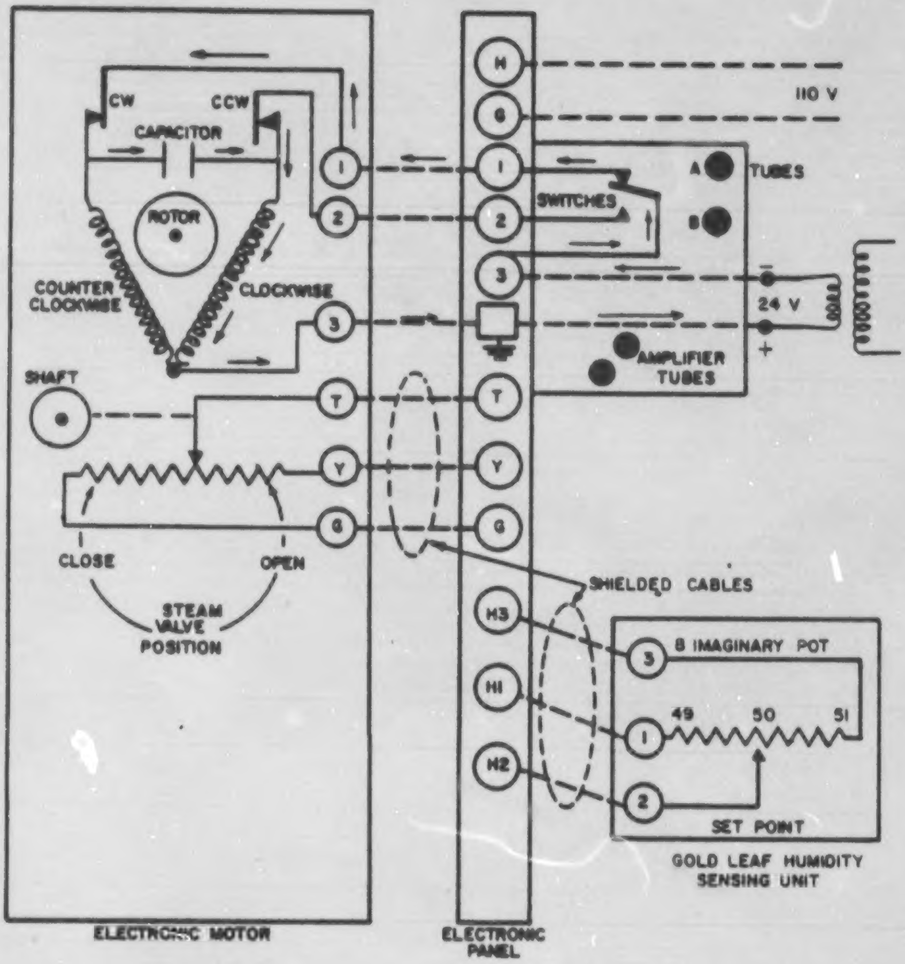

CW
CCW
CAPACITOR
ROTOR
COUNTER CLOCKWISE
CLOCKWISE
SHAFT
CLOSE
OPEN
STEAM VALVE POSITION
ELECTRONIC MOTOR
H
G
110 V
1
2
3
T
Y
G
SWITCHES
A
B
TUBES
24 V
AMPLIFIER TUBES
SHIELDED CABLES
H3
H1
H2
8 IMAGINARY POT
49
50
51
SET POINT
GOLD LEAF HUMIDITY SENSING UNIT
ELECTRONIC PANEL

Figure 75. Electronic Humidity Control with Simplified Wiring Diagram

SUMMARY

When an alternating current bridge is unbalanced to the right and gives a positive signal, it will, if unbalanced to the left, give a negative signal. If the unbalanced bridge to the right produces a voltage which is in phase with the line voltage, then the unbalanced bridge to the left will produce a voltage which is 180 degrees out of phase with the line voltage.

The discriminator circuit is capable of determining the direction in which the bridge is unbalanced. It can, therefore, prepare switching which will cause a valve or damper to operate in a direction which will correct the condition which caused the bridge to be unbalanced.

Discriminator tubes will conduct only when the plate is positive and when the signal on the grid is positive.

Humidity, temperature, and pressure may be controlled electronically through the use of the bridge and discriminator circuits.

QUESTIONS

1. What is thermionic emission?

2. How can electron flow be increased in the diode tube?

3. The diode tube has how many elements?

4. What type of transformer is used for full-wave rectification?

5. What are two components of the filter circuit?

6. What are the internal components of a diode tube?

7. Define the term "semiconductor."

8. What is a P-type semiconductor material?

9. What is an N-type semiconductor material?

10. What are the two elements of the solid state diode?

11. What are the three elements of a transistor?

12. Why are impurities added to pure semiconductor material?

13. If the control grid in the triode tube is made more negative, what is the result?

14. As relative humidity goes up, what happens to the resistance of the gold leaf grid?

15. As the temperature goes up, what happens to the resistance of the Balco wire thermostat?

16. Will current flow through a balanced electronic bridge?

17. What is the purpose of the amplifier tubes?

18. When will a discriminator tube conduct?

19. What is the purpose of the discriminator tube in the phase detector circuit?

20. What adjustment is used in the electronic control loop to center the motor?

REFERENCES

1. AFM 52-7, Elementary Electricity
2. AFM 52-8, Electronic Circuit Analysis
3. Minneapolis-Honeywell Electric and Electronic Controls Manual
4. Electricity One-Seven, Harry Mileaf

353

TROUBLESHOOTING ELECTRICAL CONTROLS

OBJECTIVE

This project will develop your skill in using an ohmmeter to locate shorts and opens in an electrical control circuit.

PROCEDURE

NOTE: Very often an electrical control circuit will be very long and the wires may be located inside of a conduit. In troubleshooting these, you must find the malfunction by checking at the outlet boxes only.

1. Use an ohmmeter and check each wire.
2. Record the trouble found in the space provided.
3. Turn all switches to the OFF or ON position before troubleshooting.

OFF	ON
a. ______________________	a. ______________________
b. ______________________	b. ______________________
c. ______________________	c. ______________________
d. ______________________	d. ______________________
e. ______________________	e. ______________________

4. Return all equipment to its proper place.

Checked by ______________________
(Instructor)

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WORKBOOKS 3ABR54530-VII-4-P1 thru P5 and
3ABR54530-VII-5-P1 and P2

Department of Civil Engineering Training

Refrigeration and Air-Conditioning Specialist

ELECTRICAL AND ELECTRONIC CONTROLS

July 1975

SHEPPARD AIR FORCE BASE

11-8

Designed For ATC Course Use

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VII-4-P4	Operation and Adjustment of Series-60 Control Loop	July 1975	7
VII-4-P5	Operation, Adjustment, and Troubleshooting of Series-90 Controls	July 1975	9
VII-5-P1	Identification and Purpose of Conventional and Solid State Devices	July 1975	12
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This supersedes SGs 3ABR54530-VII-4 thru 5, WBs 3ABR54530-VII-4-P1 thru P5 and 3ABR54530-VII-5-P1 and P2, October 1973
(Superseded publication may be used until stock is exhausted.)

Dept of Civil Engineering Tng
Sheppard AFB, Texas

WB 3ABR54530-VII-4-P1
July 1975

TROUBLESHOOTING ELECTRICAL CONTROLS

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1. Use an ohmmeter and check each wire.

2. Record the trouble found in the space provided.

3. Turn all switches to the OFF or ON position before troubleshooting.

OFF	ON
a. ____________________	a. ____________________
b. ____________________	b. ____________________
c. ____________________	c. ____________________
d. ____________________	d. ____________________
e. ____________________	e. ____________________

4. Return all equipment to its proper place.

Checked by ____________________
(Instructor)

WB 3ABR54530-VII-4-P2
July 1975

OPERATION AND ADJUSTMENT OF SERIES-20 CONTROLS

OBJECTIVE

The purpose of this exercise is to assist you in learning to connect, adjust, and operate a two-position electrical control circuit.

Connecting a Two-Position Electrical Control Circuit

1. Connect the 3-wire signal and power circuit and indicate the switch movement on a rise in variable in figure 1.

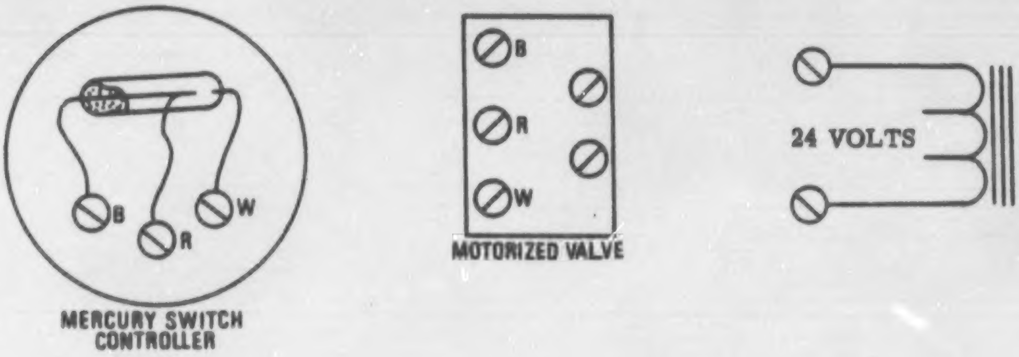


Figure 1. Control Circuit

CAUTION: Remove your jewelry, observe safety precautions, and keep hands off hot terminals.

2. Secure the following equipment:
   a. Stepdown transformer, 110V to 24V.
   b. Radiator valve.
   c. Series-20 two-position electrical controller.
   d. Wire
3. Connect the wires as indicated in your drawing, figure 1.
4. Have the instructor check your wiring.

Operation and Adjustment of Two-Position Electrical Controls

1. Connect transformer to source of power.
2. Move controller set point to lowest point.
3. Turn thermostat up.
   a. This simulates a room that is cold and calling for steam.
   b. What is the action of the two-position control? ______________________

____

____

____

4. Turn thermostat down.
   a. This simulates a warm room inwhich steam is no longer needed.
   b. What is the action of the two-position control? ______________________

____

____

____

5. Adjust the set point to the desired condition.
   a. What determines the desired condition? ______________________

____

   b. What advantage does the series-20 have over a snap-action type valve?

____

____

   c. What is the differential of this controller? ______________________

____

6. Have the instructor check your work.
7. Disconnect all equipment and return it to its proper place.

Checked by ______________________
(Instructor)

OPERATION AND ADJUSTMENT OF SERIES-40 AND SERIES-80 CONTROL LOOPS

OBJECTIVE

Each of you will wire, adjust, operate, and troubleshoot a series-40 or series-80 two-position control loop.

Connecting the Two-Position Electrical Control Circuit

1. Draw lines to indicate proper wiring, see figure 2.

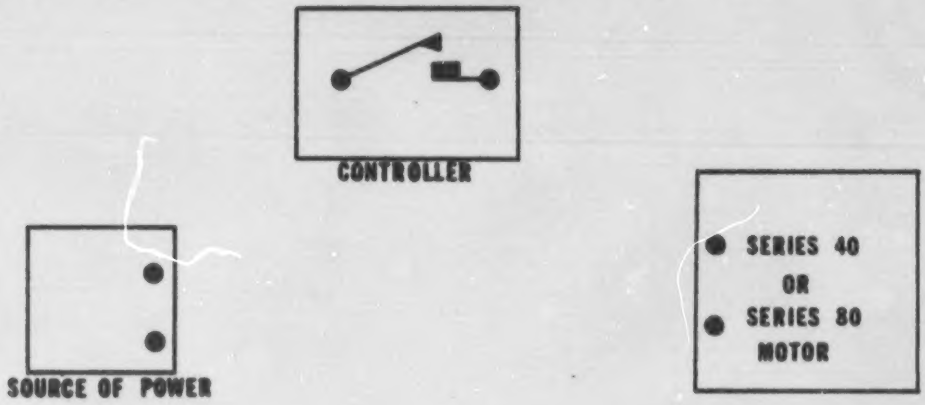


Figure 2. Control Circuit

2. The series-40 control circuit is supplied with ______________ volts.

3. The series-80 control circuit is supplied with ______________ volts,

   and therefore must use a ______________________ to reduce the power supply.

   CAUTION: Remove your jewelry, observe safety precautions, and keep hands off hot terminals.

4. Secure the following equipment:

   a. Stepdown transformer (for series-80 control loops)

   b. Series-40 or series-80 motor

   c. Two-position pressuretrol

   d. Wire

5. Connect the wires as indicated in your drawing, figure 2.

6. Have the instructor check your wiring.

Operation and Adjustment

1. Calibration of the pressuretrol.
   a. Apply set point pressure.
   b. Set differential to minimum
   c. Level controller
   d. Adjust cut-in and cut-out.
   e. Adjust scale plate, if necessary.
2. Increase the pressure above the cut-in setting.
3. Explain the reaction of the control loop: ______________________________

   ____
4. Decrease the pressure below cut-out.
5. Explain the reaction of the control loop: ______________________________

   ____
6. While the motor is running, disconnect the source of power.
7. Explain the reaction of the control loop: ______________________________

   ____
8. When is the brake solenoid energized? ______________________________

   ____
9. What is the purpose of the brake solenoid? ______________________________

   ____
10. If the brake solenoid develops an open, how would the motor react? ______________

    ____

11. What is the full power stroke of this control loop? ____________________

____

12. Disconnect all equipment and return it to its proper place.

Checked by ____________________
(Instructor)

OPERATION AND ADJUSTMENT OF SERIES-60 CONTROL LOOP

OBJECTIVE

The purpose of this exercise is to develop your skills in connecting, adjusting, and operating the series-60 controls

Connecting the Floating Electrical Control Circuit.

1. Draw lines to indicate proper wiring, figure 3.

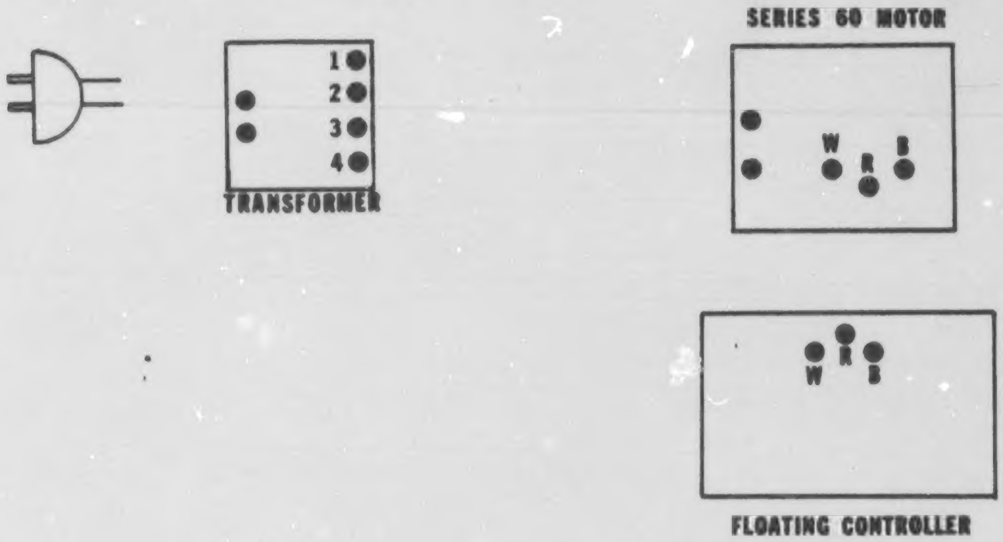


Figure 3. Control Circuit

CAUTION: Remove all jewelry, observe safety precautions, and keep hands off hot terminals.

2. Secure the following equipment:
    a. Stepdown transformer
    b. Series-60 motor
    c. Controller
    d. Wire
3. Connect the wires as indicated in your drawing, figure 3.
4. Have the instructor check your wiring.

Operation and Adjustment

1. Adjust the controller to indicate a decrease in variable.
2. What is the reaction of the motor? ______________________________
3. Adjust the controller to indicate an increase in variable.
4. What is the reaction of the motor? ______________________________
5. What is the purpose of the limit switches? ______________________________
6. Explain the term "floating" as it applies to the series-60 control loop. ______________________________
7. Disconnect the source of power.
8. Disconnect the white wire.
9. Adjust the controller to indicate a variable decrease.
10. Connect the control loop to the source of power.
11. What is the reaction of the motor? Explain. ______________________________
12. Disconnect all equipment and return it to its proper place.

Checked by ______________________
(Instructor)

OPERATION, ADJUSTMENT, AND TROUBLESHOOTING OF SERIES-90 CONTROLS

OBJECTIVE

The purpose of this exercise is to develop your skills in connecting, adjusting, and troubleshooting series-90 controls.

Connecting the Series-90 Electrical Control Circuit

1. Draw lines to indicate proper wiring, figure 4.

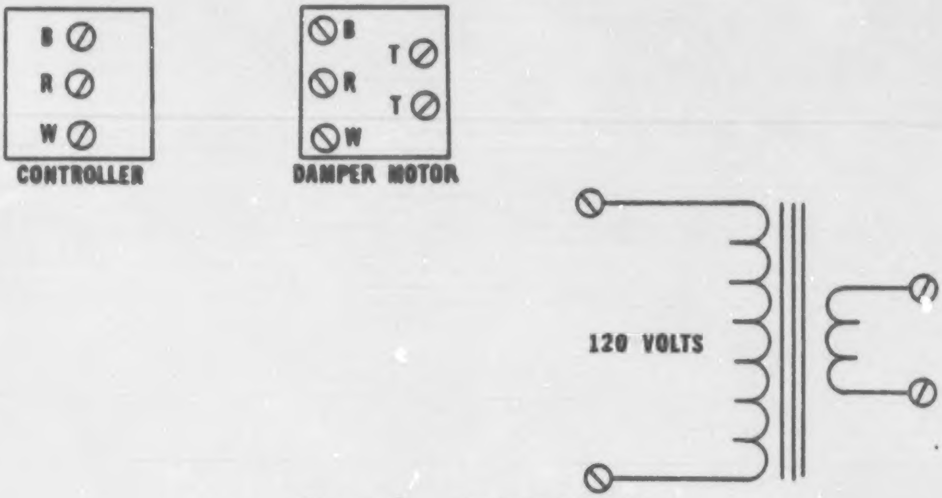


Figure 4. Control Circuit

CAUTION: Remove all jewelry, observe safety precations, and keep hands off hot terminals.

2. Secure the following equipment:
   - a. Stepdown transformer
   - b. Series-90 motor
   - c. Series-90 controller
   - d. Wire
3. Connect the wires as indicated in your drawing, figure 4.
4. Have the instructor check your wiring.

Operation and Adjustment

1. Calibrating the series-90 pressuretrol
   a. Apply set point pressure
   b. Set differential to minimum
   c. Center wiper arm. (Use ohmmeter; all wires must be disconnected.)
   d. Check scale plate; it should read set point pressure. Adjust if necessary.
   e. Set differential if desired.
2. What will cause the circuit to become unbalanced? ____________________

   ____

3. Will current flow when the bridge is balanced? ____________________

   ____

4. Connect source of power.
5. Decrease the measured variable at the controller.
6. Does the motor turn clockwise or counterclockwise (from terminal end)?

   ____

Troubleshooting

1. Increase the measured variable at the controller to position signal wiper arm at the midposition of the potentiometer.
2. Allow the motor time to rotate to a balanced position.
3. Disconnect the blue wire from the controller.
4. Turn the adjustment screw on the controller moving the wiper arm to the left. What is the reaction of the motor?

   ____

5. Turn the adjustment screw on the controller moving the wiper arm to the extreme right. What is the reaction of the motor?

   ____

6. Connect the blue wire.
7. Center wiper arm once again by turning the adjustment screw.

8. Allow the motor time to rotate to a balanced position.

9. Place a small piece of paper (this will simulate a dirty wiper arm) between the wiper arm and signal potentiometer.

10. Increase the measured variable. What is the reaction of the motor? ____

11. Disconnect all wires and return equipment to its proper place.

12. What effects will low voltage have on the control loop? ____ ____

13. How would you determine if the voltage was low? ____________________ ____

14. What would happen if the capacitor was bad? ____________________ ____

15. What effect would an open in the red lead have on the control loop? __________ ____

Checked by ____________________
(Instructor)

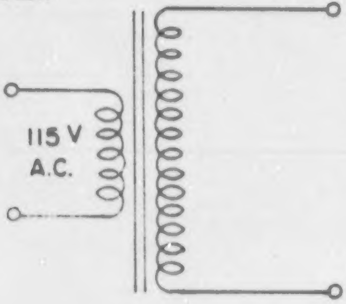
IDENTIFICATION AND PURPOSE OF CONVENTIONAL AND SOLID STATE DEVICES

OBJECTIVE

This project will aid you in learning how to identify the various components of conventional and solid state electronic control circuits. This project will aid you in learning the purpose and function of these various components that are used in refrigeration and air-conditioning controls.

1. Identify the following items and state the purpose of each item in an electronic circuit.

a.



Name: ______________________________

Purpose: ____________________________

____

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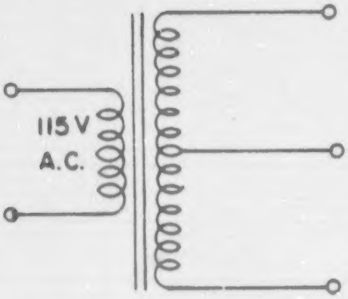
b.



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Purpose: ____________________________

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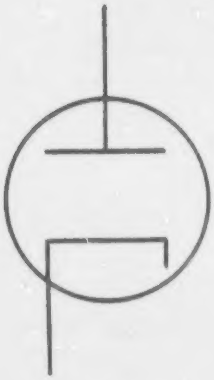
c.



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Purpose: ____________________________

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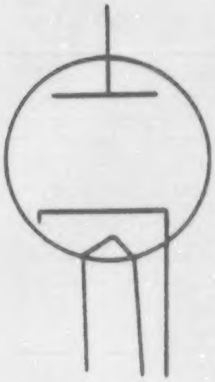
d.



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Purpose: ___________________________

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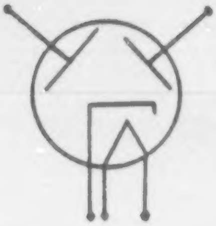
e.



Name: ______________________________

Purpose: ___________________________

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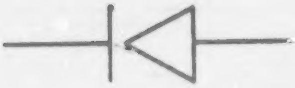
f.



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Purpose: ___________________________

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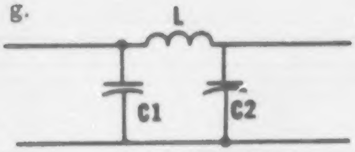
g.



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Purpose: ___________________________

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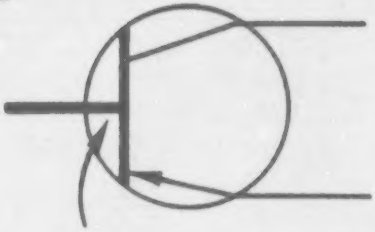
h.



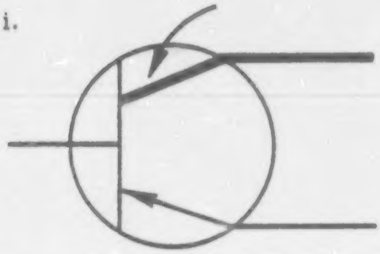
Name: ______________________________

Purpose: ____________________________

____

____

i.



Name: ______________________________

Purpose: ____________________________

____

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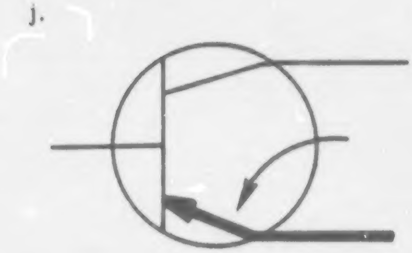
j.



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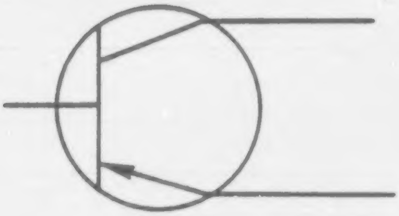
Purpose: ____________________________

____

____

k.



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Purpose: ____________________________

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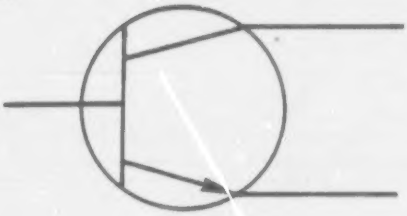
l.



Name: ______________________________

Purpose: ____________________________

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____

2. Schematically connect the following components to form a complete circuit.

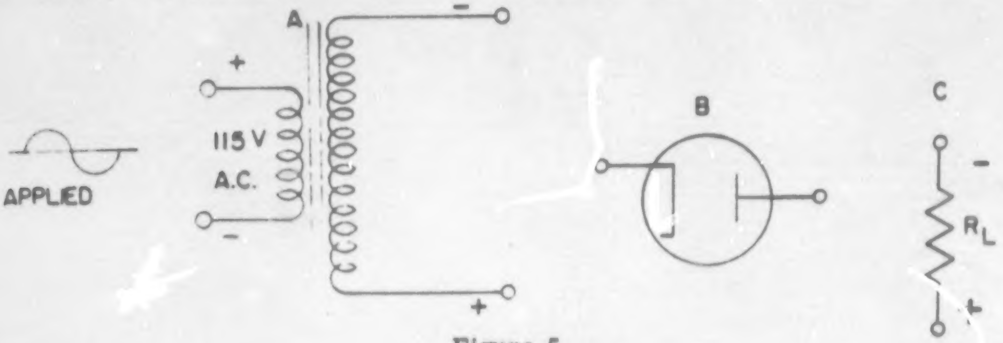

Figure 5.

3. With arrows, show the direction of current flow in this circuit.

4. Draw the waveform of the current passing through component C:

____

5. This is known as a ______________________________ circuit.

6. Schematically connect the following components to form a complete circuit.

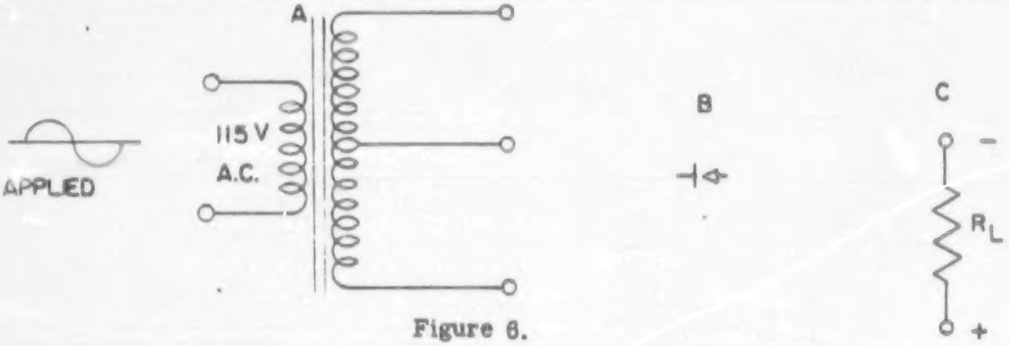

Figure 6.

7. With arrows, show the direction of current flow in this circuit.

8. Draw the waveform of the current passing through component C:

____

9. Component B is a ______________________________

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10. Schematically connect the following components to form a complete circuit:

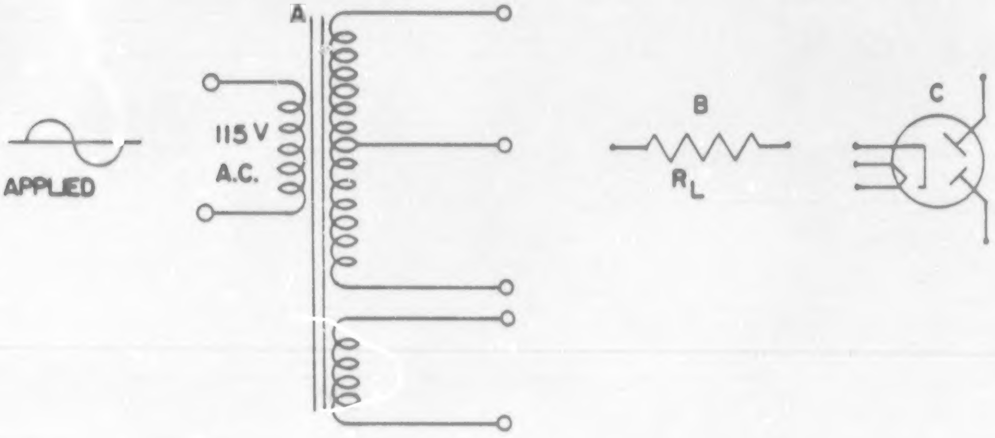

Figure 7.

11. With arrows, show the direction of current flow in this circuit.

12. Draw the waveform of the current passing through component B:

____

13. This is known as a ________________________________ circuit.

14. Identify the components: A. ____________________________

B. ____________________________

C. ____________________________

15. Answer the following questions:

a. What is the purpose of the duodiode vacuum tube? ____________________

____

b. What is the purpose of the bleeder resistor or voltage divider?

____

c. What is the purpose of the low voltage ac on the filament?

____

d. What type of transformer is used in this power supply? ____________________

____

e. What is the purpose of the filter in the power supply? ______________________

____

f. Is current through the bleeder resistor ac or dc? ______________________

g. What are the two components of the filter system? ______________________

____

16. The two types of transistors are

a. ______________________

b. ______________________

17. Transistors are used as ______________________ and ______________________ when used in electronic temperature and humidity control loops.

18. Transistors are made of what material?

______________________ and ______________________

19. What impurities are added to the transistors to make PNP transistors?

a. ______________________

b. ______________________

20. What materials are added to the transistors to make NPN transistors?

a. ______________________

b. ______________________

WIRE AND OPERATE AN ELECTRONIC HUMIDITY CONTROL LOOP

OBJECTIVE

To learn to wire electronic control circuits and how to adjust electronic controllers.

PROCEDURES

Accomplish all preoperational checks listed below prior to operation of the trainer and observe the listed procedures closely during all operation.

1. Proceed to trainer assigned by the instructor and perform preoperational checks as follows:

   a. Remove all jewelry.

   b. Check applied voltage against data plate of controllers and motors.

   c. Open all switches and remove all electrical plugs before starting projects.

2. Operational safety checks.

   a. Wire all projects as illustrated in the project diagram, figure 8.

   b. Have instructor check wiring before connecting electrical equipment.

   c. Proceed with project, making adjustments of controllers to allow motors to operate.

3. Examine the trainer taking note of its circuit diagram. Identify the following (on trainer and diagram, figure 8.

   a. Electronic control panel.

   b. Modulating motor.

      (1) What is the source of power for the modulating motor?

      ____

      (2) The motor operates on ______________________ volts.

   c. Stepdown transformer (external).

   d. Controller with its gold leaf measuring element.

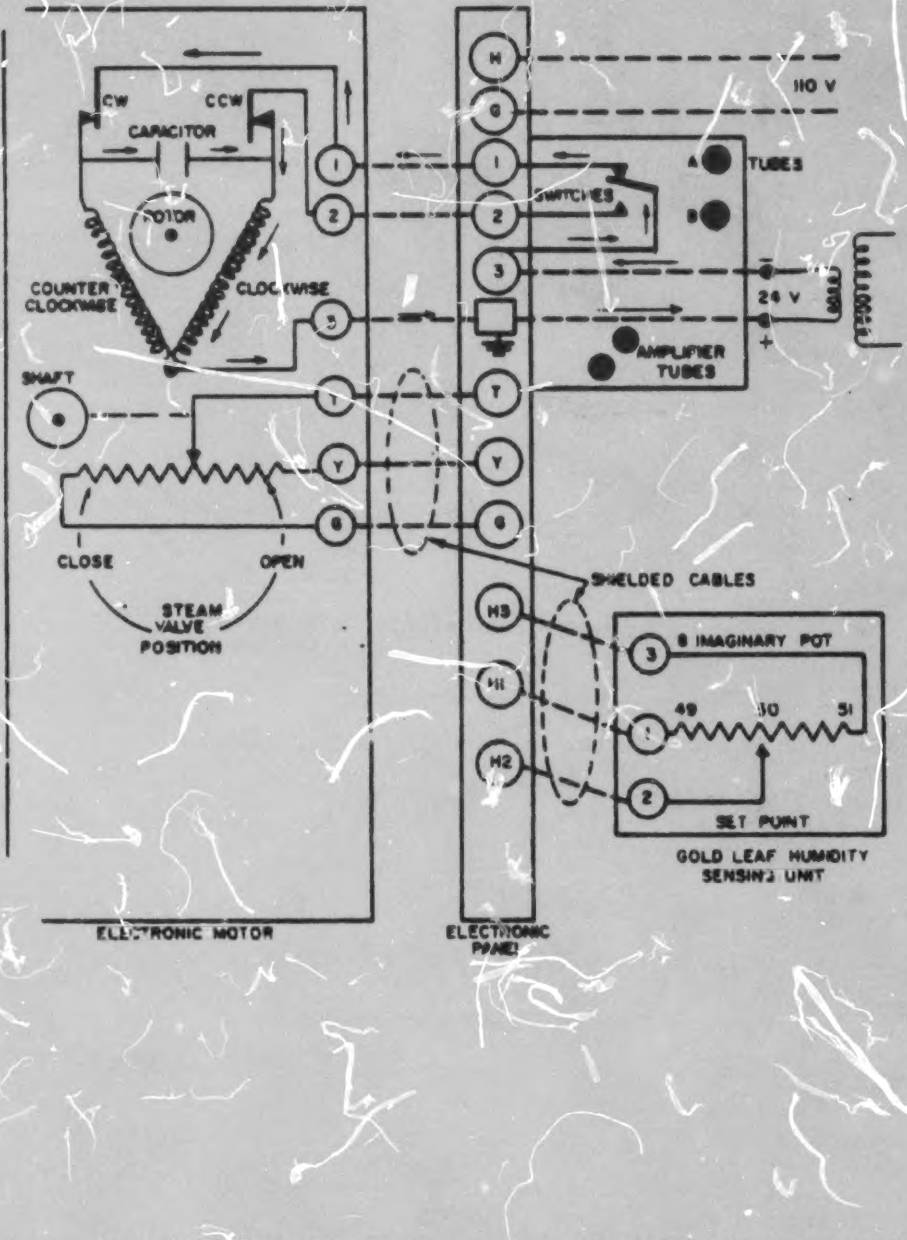
CW
CCW
CAPACITOR
ROTOR
COUNTER CLOCKWISE
CLOCKWISE
SHAFT
CLOSE
OPEN
STEAM VALVE POSITION
ELECTRONIC MOTOR
1
2
3
T
Y
G
H
G
1
2
3
T
Y
G
110 V
TUBES
A
B
SWITCHES
24 V
AMPLIFIER TUBES
SHIELDED CABLES
H3
H1
H2
3
1
2
8 IMAGINARY POT
49
50
51
SET POINT
GOLD LEAF HUMIDITY SENSING UNIT
ELECTRONIC PANEL

Figure 8. Electronic Humidity Control with Simplified Wiring Diagram

375

e. Circuit breaker.

(1) What size circuit breaker protects the trainer circuits?

____

(2) What size fuse protects the bridge circuit transformer?

____

4. Remove the electronic control panel cover. Locate the terminal board and identify the wiring connections on the terminal board and diagram. Locate the following on the control panel.

a. Amplifier discriminator assembly.

b. Balancing relays.

(1) Where would the balancing relay be found in an electronic control system?

____

(2) What operates the balancing relays found on the panel?

____

c. Control point adjustment.

d. Throttling range adjustment.

5. Wire the trainer as indicated in the diagram furnished.

6. Have the instructor check your wiring.

7. Set the throttling range to 10, the control point adjustment to 0.

8. Turn the power switch ON and observe the motor operation.

NOTE: If the motor does not operate, change the adjustments (in step 7) to the necessary values to make the motor turn to a midrotation position.

9. With the motor at midrotation, expose the measuring element to moist air by blowing on it through the small holes in the cover.

What direction did the motor shaft turn? ________________________

10. Allow the room air to dry the measuring element.

NOTE: This may take a few minutes.

What direction did the shaft turn? ______________________________

11. Postoperational checks

    a. Disconnect equipment electrically.

    b. Remove wiring from trainers.

    c. Replace all equipment.

12. Have instructor check your work.

Checked by ______________________
(Instructor)

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STUDY GUIDES
3ABR54530-VIII-1 thru 3

Technical Training

Refrigeration and Air Conditioning Specialist

TYPICAL AIR-CONDITIONING EQUIPMENT AND PSYCHROMETRICS

October 1975

USAF SCHOOL OF APPLIED AEROSPACE SCIENCES
Department of Civil Engineering Training
Sheppard Air Force Base, Texas

11-8.

Designed For ATC Course Use

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This supersedes Study Guides 3ABR54530-VIII-1 thru 3, October 1973 and Workbooks 3ABR54530-VIII-1-P1 thru 3-P2, October 1973
(Copies of the superseded publications may be used until the supply is exhausted.)

Department of Civil Engineering Training
Sheppard Air Force Base, Texas

SG 3ABR54530-VIII-1
15 October 1973

AIR-CONDITIONING EQUIPMENT

OBJECTIVE

This study guide is designed to aid you in learning about air conditioning. It will provide you with instruction concerning the various equipment used in air conditioning, make a comparison of air conditioning and refrigeration, and point out the goals established for air conditioning.

INTRODUCTION

As early as 1500 AD man was designing devices to cool and ventilate his domestic environment. Methods such as water-driven devices, gear-driven devices, and other attempts gradually gave way to our modern concept of air conditioning. Improved technology has expanded this field from domestic to industrial, commercial, military, aviation, transportation, marine, and outer space utilization. In the early 1900's air conditioning was used to control the manufacture of many products (candy, matches, etc). In the 1920's air-conditioning principles were applied to commercial uses such as theaters. This was the birth of our controlled environment application for air conditioning as we know it today.

Air conditioning is defined as "that process used for the control of temperatures, humidity, filtration, and circulation of air." Air conditioning is playing a more important part in man's environment. His home and automobile, business, and recreational locations are air-conditioned in order that the maximum comfort may be maintained, increasing the efficiency of the activity being performed.

TYPES AND APPLICATIONS OF AIR-CONDITIONING EQUIPMENT

Air conditioners are designed to fulfill the definition that "air conditioning is the control of temperature, humidity, filtration, and circulation of air." There are several applications for air conditioners; they include comfort cooling, equipment cooling, process cooling, and transportation cooling. As there are many applications, there are many types of units. The 545X0 Career Field has the responsibility for the service and maintenance of these many types of equipment. Some of the general classes of equipment are discussed in the remaining pages of this study guide.

Window Units

Window units are compact, efficient units that are designed to cool a small area. A unit is normally installed in a window; however, it can be installed in a hole in a wall with the cooling coil section on the inside and the condenser section on the outside. Window units are manufactured in sizes ranging from 3,000 Btu - 36,000 Btu per hour capacity. Smaller units usually less than 10,000 Btu operate on a 120v ac circuit, while the larger units usually require 240v ac single-phase power.

Industrial Units

These systems are as large and complex as required to produce the conditions needed. They can vary in size from 25 tons to 10,000 tons per system. They can be used in the fields of manufacturing, communications, and data automation, just to name a few.

Portable Units

Portable systems are found in many styles and types. They are self-contained; some have gasoline-driven engines as a power source. Some are wheel-mounted for mobility. They are used for primary or backup systems in the fields of aviation, communications, and photography.

SIMILARITIES OF AIR-CONDITIONING EQUIPMENT

Compressor Types

Earlier in the course, you found that compressors are classified as hermetic, semihermetic, open, or centrifugal. Any of these compressors is liable to be found in field applications, depending on the system's size.

HERMETIC COMPRESSORS. Hermetic compressors are sealed, self-contained units which can employ either the reciprocating or rotary compression method. The rotary compressor is used with refrigerators, water coolers, and small capacity equipment up to approximately 2 hp. The larger reciprocating compressors used in window units, residential units, commercial, and industrial systems can be as large as approximately 10 hp and must be positively lubricated because of the sealed housing.

SEMIHERMETIC COMPRESSORS. Semihermetic compressors are extremely desirable in applications where low range temperatures are used. They can be serviced, but they do not contain a shaft seal. The units are more free of vibrations, and the motor is more positively lubricated, plus the suction gas aids in keeping the motor windings cool. These units normally run 5 - 15 hp.

OPEN COMPRESSORS. Open compressors are always field serviceable and are popular because they will not contaminate the entire system with acid if the motor should burn out. They can employ a direct drive or belt-driven connection.

They do require a shaft seal and, if a direct drive is used, a flexible coupling. If multiple speeds are desired a gear train can be applied or variable speed pulleys incorporated easily on this type unit. Should a different motor be used, pulleys can be installed or changed to insure proper rpm. The open type compressor can be as large as 50 hp rated per unit.

CENTRIFUGAL COMPRESSORS. These are designed to produce a large volume of refrigerant flow at a low pressure differential. Centrifugal force causes the compression to take place. The unit can be staged to effect even better operation. This type unit will normally be used in systems in excess of 100 tons. However, a smaller system has been designed for aeronautical use on aircraft environmental control.

Evaporators

The evaporator or cooling coil is the device which picks up the heat in the controlled space causing the boiling of the refrigerant and changing the state from HPHT liquid to an LPLT gas. There are two types of evaporators, flooded and dry. The dry evaporator is always filled with a mixture of liquid refrigerant and vapor and must employ some method of expansion by use of a metering device, such as a capillary tube, AEV or TEV. This type of system, if applied to the air source being cooled, is known as a direct expansion (DX) cooling coil. The exchange of heat is accomplished by using a fin-and-tube or plate-type assembly.

In a flooded system a constant level of refrigerant is maintained by a float valve assembly. This method is very popular in chiller operations using a shell-and-tube or tube-within-a-tube assembly. This can be used in a direct expansion system, or, if chilled water is to be supplied to a remote coil as a secondary refrigerant, we have an indirect expansion (IX) application.

Evaporator temperature ranges will vary, however, for air-conditioning work the apparatus temperature is normally from 35° - 45°. Most cooling coils are designed at 40° which will produce 52° air at the coil for supply purposes. Air temperature will vary with changes in air volume through coils.

Condensers

Condensing systems are divided into three groups according to size. 'Small systems from one to three horsepower, medium systems from five to one hundred horsepower, and systems 100 hp and over, called large installations. The type used will depend on the size of the installation. Generally, fractionally sized units (1/4 to 1 hp) are self-contained.

At our disposal are three methods to effect the condensing process. There are air-cooled, water-cooled, and evaporative-cooled condensers. Air-cooled condensers are restricted to small and medium size installations. Water-cooled condensers are restricted only by water supply (condition and availability) and maintenance expense. They are used on systems sized from 3 tons to the largest size made.

Evaporative condensers operate on the principle that water evaporated to the air dissipates heat to the atmosphere. This heat is approximately 1000 Btu/pound of water evaporated.

Keep in mind that the condenser's function is to discharge the heat picked up in the evaporator and also the heat of compression, which is approximately 10 percent of the total heat being dispelled. In the condensing cycle there are three stages. The hot gas entering must be desuperheated (change gas to a vapor). It is then condensed (vapor to a liquid) and finally it is subcooled (removal of excess temperature and pressure). Non-condensable gases will collect in the condenser or receiver and can be vented or purged from this point in the system when they affect the unit's operation. Some systems, usually centrifugal, have a separate unit (purge unit) which will automatically perform this function.

Metering Devices

The function of the metering device is to control the flow of the refrigerant to the evaporator so as to keep the evaporator fully active during the entire cycle. This means that the refrigerant is boiling throughout the evaporator, except for the small section reserved for superheat. The normal superheat setting is factory set at 7°F but in operation will give us a 10°F superheat setting.

THERMOSTATIC EXPANSION VALVES. Thermostatic expansion valves were designed to maintain a constant evaporator superheat by distributing the refrigerant at a rate which will keep the evaporator fully active. The addition of the feeler bulb element sensing device, placed at the outlet, aids in maintaining this constant superheat by varying the volume of gas being fed to the evaporator, according to the load being handled. On some models a multiple distributor is used to feed smaller volumes of the total vapor into equal segments of the evaporator to provide a more even flow of refrigerant through the evaporator. Other applications use an external equalizer line which is incorporated to compensate for excessive pressure drops across the evaporator.

CAPILLARY TUBE. Capillary tubes are used as the metering devices in small systems. They are acceptable if a constant load is required. They are low cost items and eliminate the need for higher cost expansion valves and liquid receivers. The systems using capillary tubes are all critically charged since the units are designed to maintain a constant load. Normally capillary tubes are not used on systems larger than three tons capacity.

Insulation

Insulation is used for two main reasons. Primarily, it is to retard heat flow and secondarily, to reduce noise. This is determined by the type selected and the physical placement of the material. By applying your knowledge of transmission heat gains, you can better determine the type of insulation required to maintain the temperature in the ducts.

The materials surrounding a heat source vary in their ability to conduct heat just as insulations vary in their retarding ability against heat transfer. Materials capable of of retarding heat effectively must be composed of tiny, totally enclosed air cells or fibers. Some insulation material consists of hairfelt, mineral wool, fiberglass, asbestos, cork, or foam. In the event the insulation requires moisture retardation as well, a material such as asphalt, tar, or polyethylene sheeting is added. If a reflective insulation is required, then aluminum or some reflective quality material is added. For an insulation to be effective, it should contain as many of the following characteristics as possible.

LOW THERMAL CONDUCTIVITY (K-FACTOR). This is the amount of heat that will pass through a 1-square foot area, 1 inch thick, in one hour with a TD of 1°F.

RESISTANCE TO SETTLING. Some materials will settle so that after a few years the top 4 - 5 inches of the wall will not be insulated. Therefore, loose type materials should not be used in vertical walls.

MOISTURE RESISTANCE. Moisture resistance of a material affects the heat retarding ability of an insulation. If an insulation becomes laden with moisture there is practically no retardation of the heat transferring through the area insulated. Some materials will swell with the addition of moisture; therefore, could cause walls to swell, and in colder climates could freeze causing damage to insulation and surrounding areas.

FIRE RESISTANCE. Materials should be nonflammable, nontoxic, and noncombustible as possible. Some of the materials that are nonflammable include foam glass, glass wool, perlite, vermiculite, mineral wool, asbestos wool and redwood bark.

VERMIN RESISTANCE. Rats, mice, and other forms of vermin render some insulation worthless in a very short time.

LIGHT WEIGHT. If the insulation is not strong enough to support itself, a heavy wall must be provided to support it. The weight of the insulation must be figured to determine the added support needed for the ceiling.

DETERIORATION RESISTANCE. Deterioration is generally caused by chemical reaction, accelerated by moisture. A chemical treatment must be used on materials which are water absorbing to retard rot, mold, or other deterioration elements.

DENSITY. The heavier the insulation the stronger must be the supporting structure (walls, ceiling, floors, etc).

Other areas of consideration, such as the specific heat, odor, ease of installation, and cost must also be weighed in the selection of the best insulation for the job to be done.

Fans

Air is moved by mechanical means in an air-conditioning system. The fan converts mechanical energy (fan blade rotation) into gas energy (airflow). This is accomplished by means of a wheel or blade, imparting a spin on the air so that it will leave the fan assembly in a forward motion to the point of destination.

Fans are classified into two major categories: AXIAL and RADIAL.

Types of Fans

AXIAL FANS. These fans move air in a flow parallel to the shaft. The air will have a spiral motion, but will be moving in a parallel plane. Axial fans have three blade classifications.

Propeller Fan Blades. Propeller fan blades are found on the pedestal or table fan common to home use. Fans of the ceiling variety use propeller blades. These fans are used to move air within a given area (circulation). Normally, they have a safety shroud around them and operate satisfactorily against static pressures of 1/2 to 3/4 inch water pressure. They can be used only if a low volume of air movement is required and normally are used for exhaust or ventilation purposes. They can be direct drive or belt driven, see figure 1.

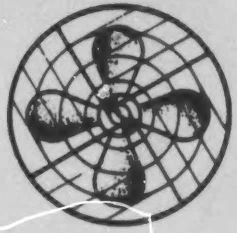


Figure 1. Propeller Fan

Tube-Axial Fans. They are used for heavier duty air movement. They are built for mounting in ductwork whereas the propeller type is mounted in a wall. Since the air will move at a higher velocity, the increase of the spiral movement will incur greater duct pressure losses, and will increase the amount of noise in a duct system. For this reason they are normally used for industrial applications where noise is a minor consideration, and space is of no concern. The tube-axial fans can withstand pressures up to 2 1/2" to 3" water pressure. They are also direct drive or belt driven. The propeller fans of all types have the added characteristic of using most power at maximum air delivery. See figure 2.

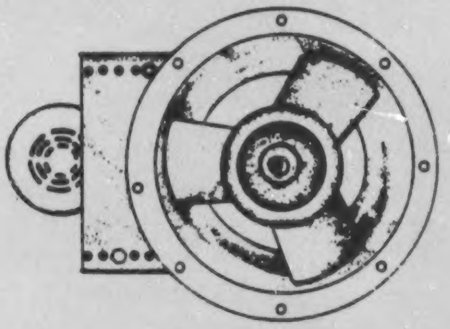


Figure 2. Tube-Axial Fan

Vane-Axial Fans. These fans are in reality nothing but a tube-axial fan with vanes installed in the fan housing. The vanes are used to staighten out the spiraling motion of the air. This offers the added factor of less noise and increased efficiency. The vane-axial fan can withstand pressures up to 3" water pressure (see figure 3).

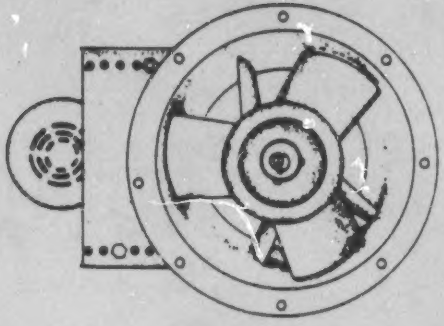
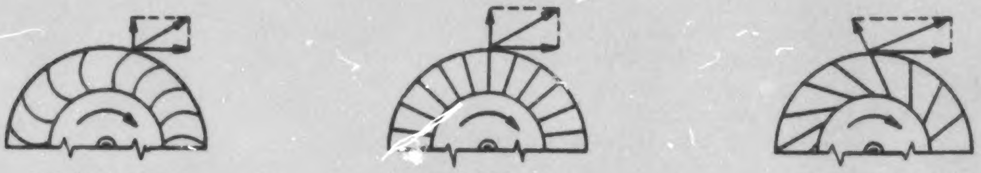


Figure 3. Vane-Axial Fans

RADIAL FANS. They move the air into the blower housing parallel to the shaft but discharge it radially to the shaft (see figure 4). This means that the air is discharged at a 90° angle or plane from the shaft of the fan. The centrifugal fan consists of a wheel (sometimes called a squirrel cage) mounted horizontally on a shaft, which rotates within the housing. Air enters parallel to the axis through the fan housing. The air may enter at either one or both ends of the wheel. The centrifugal fan will operate with less noise, but consume more power under maximum air delivery when compared to an axial flow fan.



FORWARD CURVE BLADE

RADIAL BLADE

BACKWARD INCLINED BLADE

Figure 4. Fan Blades

Air-conditioning specialists often refer to centrifugal fans as blowers. There are some factors which will be used in the determination of the fan type to be used for a particular application. They include:

- Unit size
- Drive motor selected
- Internal layout of the unit
- Shape of the coil
- Resistance of system ducts

Fans are used to ventilate (induce fresh air), circulate the same air in a system, or to exhaust odor-laden air which is part of the ventilation-circulation process.

Controls

Controls used in air-conditioning applications can be electric, electronic, and pneumatic. This segment of your training was covered in earlier blocks of the school; however, as a means of review, here is a list of some of the controls you will find in this type work.

Temperature - Thermostats of all three types.

Humidity - Humidistats of all three types.

Pressure Controls - High Pressure Motor Control
Low Pressure Motor Control
Oil Pressure Safety Control

Selector Switches - Devices which, depending on the position, will determine an operational mode or sequence.

Accessory Equipment

You have studied a number of accessory items such as mufflers, driers, sight glass indicators, Schrader valves, crankcase heaters, and service valves. Also included in this general class would be items such as strainers, boilers, sumps, traps, pumps, and regulator valves.

Filters

One of the major functions of an air-conditioning system is to deliver clean air to the controlled space. Just as temperature and humidity must be controlled, the air content in regard to dust, pollen, odors, and bacteria can be controlled.

Nearly all systems introduce a certain amount of "fresh air" into the system. This fresh air is brought in from an outside source, and it will contain foreign matter that is undesirable for conditioned air; therefore the filter has a vital role in the air-conditioning system. Keep in mind that any combination of filtering devices can be used together or in different combinations so that the desired condition is reached.

Filters are classified as PERMANENT or THROWAWAY (DISPOSABLE). Permanent filters can be cleaned and reused over and over. Disposable filters are used on a one-time basis.

The dry-type filter is of either type of construction. The throwaway filter is normally composed of a cardboard frame with cotton, fiberglass, paper, gauze, or glass wool in the center. When the material is dirty, the filter is discarded and replaced with a clean filter. These are the most common in home units and smaller systems or industrial systems where maintenance time is limited.

The permanent filter has a metal frame and a washable center filler usually of aluminum or some other synthetic product. When it becomes dirty, it is removed and cleaned with warm soapy water and air pressure, if needed.

The viscous type filter has the most use. It is a filter of either type that has been impregnated with oil. As the air passes through the filter, the dust particles adhere to the oil film. When the filter becomes dirty, it can be thrown away or cleaned, depending on the type in use. If the cleanable filter is used, once it is cleaned a coat of filter oil must be applied and any excess oil should be drained off for a period of not less than 10 to 12 hours.

The electrostatic precipitator or electronic air filter is the best type of air cleaning device. It operates on the principle that particles in the air possess a positive charge that will be attracted by a negative charge.

The air is passed through a highly ionized field (see figure 5). The electrons in the field put a charge on the particles that pass through the field of plates or grids (containing a potential of 6,000 - 12,000v dc, depending on the size of the unit). The air with its charged particles then passes through a field of plates and the opposing charge will attract and hold the particles to the plates, which can be cleaned periodically.

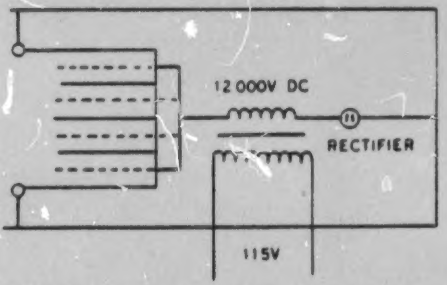


Figure 5. Electrostatic Precipitator

To clean them, cut off the power, remove the plate section, clean, let dry and then reinstall in the system. The collector pads found in some units collect matter that breaks loose and they must be replaced or cleaned periodically.

Air Purification Devices

Not truly classified as filters are the air purification devices. These items are used to remove odor, bacteria, etc.

CARBON OR CHARCOAL. These are used for odor control. Often air that is brought in from the outside is heavy laden with industrial odors and other contaminants. The charcoal will absorb the odors. To reactivate charcoal it must be baked in an oven for a given amount of time at a set temperature, depending on the type being used.

ULTRAVIOLET LIGHT. Ultraviolet light is used to control air that is laden with bacteria. Hospital sick rooms, isolation wards, meat processing areas, dairies, etc., all use ultraviolet light to control bacteria in the air and maintain purity.

Filter Maintenance

As a filter becomes clogged or dirty, the velocity pressure of the system is reduced and the efficiency of the system suffers considerably. Filter cleaning involves the following steps in the sequence listed:

1. Remove the clogged filter and replace with a clean one.

2. Clean the dirty filter with hot water, soap, and pressure if needed.

3. Allow to drain dry.

4. Dip the filter in odorless filter oil, or apply a sprayed coat of oil.
5. Allow excess oil to drain off or a centrifugal machine can be used to sling off the excess oil.
6. Place the filter in storage until needed as a replacement.

Filters must be checked periodically to insure their degree of efficiency. They should be cleaned as often as conditions require. The general allowable pressure drop is .25" water pressure. This is measured with a draft gage.

WINDOW UNITS

Window units (see figure 6) are compact, efficient units that are designed to cool a small area. A unit is normally installed in a window; however, it can be installed in a hole in a wall with the cooling section on the inside and the condenser section on the outside. Window units are manufactured in sizes ranging from 3,000 Btu - 36,000 Btu per hour capacity. Smaller units, usually less than 10,000 Btu, operate on a 120-volt ac circuit while the larger units usually require 240-volt ac single-phase power.

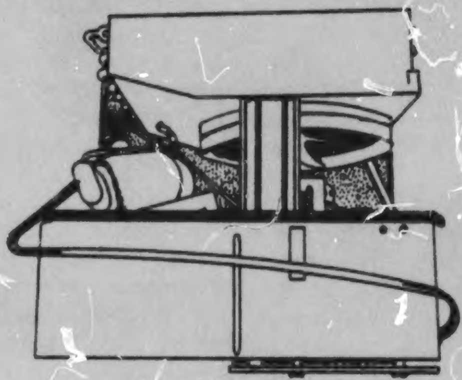


Figure 6. Window Unit (Top View)

Major Components

Window air conditioners are essentially high temperature systems. Therefore, the major components of window air conditioners are the same as for refrigeration. The components are designed for high temperature application and are used primarily for personal comfort.

FAN MOTOR. The fan motor is specially designed, rugged, two-speed motor with a double shaft. The low speed range is 875 to 950 rpm. One end of the motor shaft drives the squirrel cage blower that forces air through the evaporator. The other end of the shaft drives the blower that forces air through the condenser coil. Most of these motors have sealed bearings which require no lubrication. Most of these motors also use a small run capacitor in the circuit. The motor is subject to two main malfunctions, burnout and worn bearings. If the worn bearings aren't immediately replaced, they can be the cause of a motor burnout.

EVAPORATOR BLOWER. In order to make window units as quiet as possible, a squirrel cage blower is used to force air through the cooling coil. Squirrel cage blowers are much quieter than the blade type fans and will move a higher volume of air providing the diameter of the fans is the same. The blower is designed to move approximately 400 cfm per ton of refrigeration.

CONDENSER FAN. A fan is used to force air through the condenser. The condenser fan operates in the outside area to dissipate the unwanted heat, therefore, noise is not a major consideration. The fan blades are connected at the outer tip by a metal band which gives the blades stability, but the main purpose of this band is to pick up condensate water and sling it against the condenser. Naturally, this ring is called a slinger ring. This water aids in displacing unwanted heat through the process of evaporation adding to the efficiency of the condenser coil.

EVAPORATOR. The cooling section is usually composed of rows of copper tubing covered with aluminum fins. The collected water droplets collect at the bottom of the cooling coil and are drained through a tube or trench to the back of the unit. The slinger ring will then pick up the water and throw it against the condenser where it evaporates. The evaporator is designed to lower the temperature approximately 20 degrees. If the air entering the coil is 90 degrees and the air leaving the coil is 70 degrees, the unit is said to be performing at maximum design.

THERMOSTAT. Window units are equipped with a thermostat that cycles the compressor when the temperature reaches the set point. The thermostat usually has a fixed differential of 5 degrees and an adjustable range of 58-91°F.

CONDENSER. The condenser is usually composed of rows of copper tubing covered with aluminum fins. It is larger than the evaporator, so it can dissipate all of the heat picked up by the evaporator plus the heat of compression. The condensate water which is relatively free of scaling minerals is thrown against the condenser, thus, aiding in reducing the head pressure by making it an evaporative condenser The water thrown against the condenser causes dirt and trash to collect on the fins. As a result, the condenser must be cleaned periodically.

AIR FILTERS. Air filters used in window units are either throw away or permanent in design. They must be changed or cleaned as soon as they become dirty. This should be done as often as needed. The cleanable type should be washed in warm, soapy water, allowed to drain dry, then coated with a thin coat of filter oil. The filters reduce the amount of lint and dust in the air, but their main function is to keep the evaporator coil clean. If the air conditioner is operated without the filter in place, the evaporator becomes dirty and requires cleaning with water and air pressure.

SELECTOR SWITCH. Most window units are equipped with a selector switch having 5 positions: OFF, LOW-COOL, HIGH-COOL, LOW-FAN, and HIGH-FAN. The selections may be made by pushing a button or turning a knob. The high-speed compressor operates at a constant speed. The fan has two speeds and will operate on either high or low. When selector switches give trouble, they must be replaced.

VOLTAGE SELECTOR. Some units are designed to operate on either 208v or 230v ac. Be sure the voltage selector switch is correctly positioned for the voltage being used in the circuit.

CAPACITORS. Start capacitors are usually small in size and round in shape. They are encased in bakelite, plastic, or cardboard. Run capacitors are larger and are long, often oblong in shape, or sometimes square with the case being made of metal. The larger microfarad ratings identify the start capacitors.

COMPRESSORS. Most of the window units use the hermetic style compressor and have potential starting relays. However, many window units use a permanent split capacitor (PSC) compressor, (see figure 7). A PSC compressor has two main advantages.

1. It does not require a starting relay.
2. A small unit will produce more power because the start winding is also used for running.

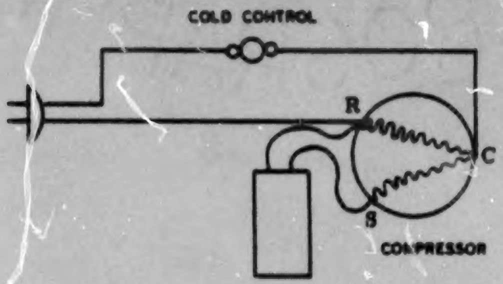


Figure 7. Wiring Diagram of PSC Compressor

REFRIGERANT. Most window units use R-22 refrigerant. The unit can be about one-third smaller in size. This is due to the fact that the heat of vaporization of R-22 is 69 Btu, compared to only 37 Btu for R-12.

Possible Troubles

Window air conditioners have the same troubles and malfunctions as other types of hermetic refrigeration units plus a few of their own. Some of the problems peculiar to window units are discussed below.

FREEZEUP. A faulty thermostat will cause freezeup. However, under certain conditions it is possible to have a freezeup with the thermostat in perfect condition. For instance, it may be warmer inside the house than it is outside. When the room thermostat temperature gets high enough, the unit will start the compressor and pull the refrigerant vapor out of the cooling coil. The head pressure is so low (due to low ambient temperature) that very little liquid refrigerant is forced through the capillary tube. Eventually the liquid going through the capillary tube is boiling below 32°F and the evaporator begins freezing at the outlet of the capillary tube. The coat of ice restricts the airflow at this point and some of the liquid refrigerant moves out of the evaporator into the suction line. This process repeats itself until the cooling coil is covered with frost. Usually a freezeup will occur at night, particularly during a cool, rainy season. Some manufacturers are installing a freezestat on the evaporator to stop the compressor if the temperature drops to 33°F. A dirty filter or evaporator will also cause a freezeup by restricting the airflow across the coil.

CLEANING. All refrigeration units require periodic cleaning. The cleaning of a window unit is particularly important. Since the condensate water is evaporated very slowly at times, it collects dirt and trash very rapidly. Window units should be removed from the window and cleaned after every cooling season. Usually the water from a hose will clean them adequately; however, in some cases you may have to use an airhose. If water is used, make sure that the fan motor is completely dry before operating the unit. Just a little water in the fan motor windings will cause the motor to burn out. Best results are obtain if steam is used. Steam cleaning requires the following special cautions:

- Be sure that the steam temperature is below the melting temperature of the copper, aluminum, or the solder used on the joints and seams.

- Be sure that the system is completely dry prior to startup of the unit. Steam will penetrate better than water and can cause motors to burn out if moisture droplets are left on the inner surfaces of the electrical components.

FAN MOTORS. As previously mentioned, there are two major malfunctions found in window units, bad bearings and burnouts. If the condition requires removal of the motor, follow the procedures as outlined:

1. Use a special long shank allen wrench to loosen blower screw.

2. Use a standard shank allen wrench to loosen the fan setscrew.

3. Either the condenser or evaporator can be moved if needed.

   NOTE: Determine which is easier to move, usually the condenser will be.

4. Remove the holding screws from the unit being moved, then lift it out of the way being careful not to kink any of the lines.

5. Remove the motor leads and mark the connections so that they can be properly reinstalled.

6. Remove the motor retaining nuts and remove the motor.

7. REPLACEMENT IS THE REVERSAL OF THIS ORDER.

8. After the replacement has been completed rotate the fan blades and be sure that they are properly aligned prior to startup of the unit. Check to be sure that all wires are attached and no tools or other objects have been left inside the unit.

9. Bench check the unit prior to reinstallation.

Installation procedures will differ a little between models and manufacturers. However, if you can install one type, you can figure out how to install any of the other types. Some general procedures are listed below.

- Install in the shade if possible.

- Guarantee complete ventilation for the condenser if possible.

- The back of the unit should be 1/2" - 1/4" lower than the front to allow proper drainage of condensate water from the evaporator.

- Support the unit securely.

- If the power cord that is supplied with the unit is not long enough, have another receptacle installed.

- Make sure that all window air conditioners are connected to a single receptacle circuit.

- In accordance with Underwriters Laboratories requirements, and for your protection and safety, special plugs have been developed for each type of unit. The proper receptacle must be used to match the plug (see figure 8).

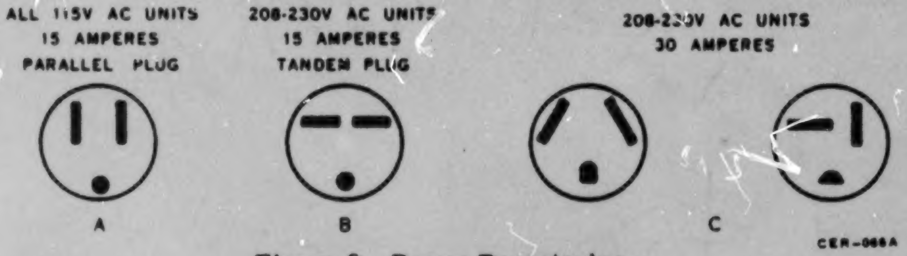


Figure 8. Power Receptacles

- Power cords for 115-120v units usually have three wires: white, black, and green. The green wire is the ground wire according to safety standard color codes. One end of this wire must be attached to the unit body and the other to the ground terminal of the plug. The black wire is the hot lead, and the white wire is the common lead.

RESIDENTIAL HOME HEATING AND AIR-CONDITIONING SYSTEM

It is not the primary duty of the 545X0 to service and repair furnaces; however, since the furnace is often an integral part of the air-conditioning system, it is necessary to understand the operation of the furnace to be able to service the air conditioner. There are several types of the central air-conditioning systems. It is impossible to cover all the makes and types. In essence, they are all the same in operation but vary in nomenclature and basic design. The system that we will discuss has a 100,000 Btu gas-fired furnace and a 38,000 Btu electrical air conditioner.

The Dual System

Since the heating and the cooling are produced in the same portion of the package (the furnace body), let's look at the overall basic structure of the combined units as shown in figure 9.

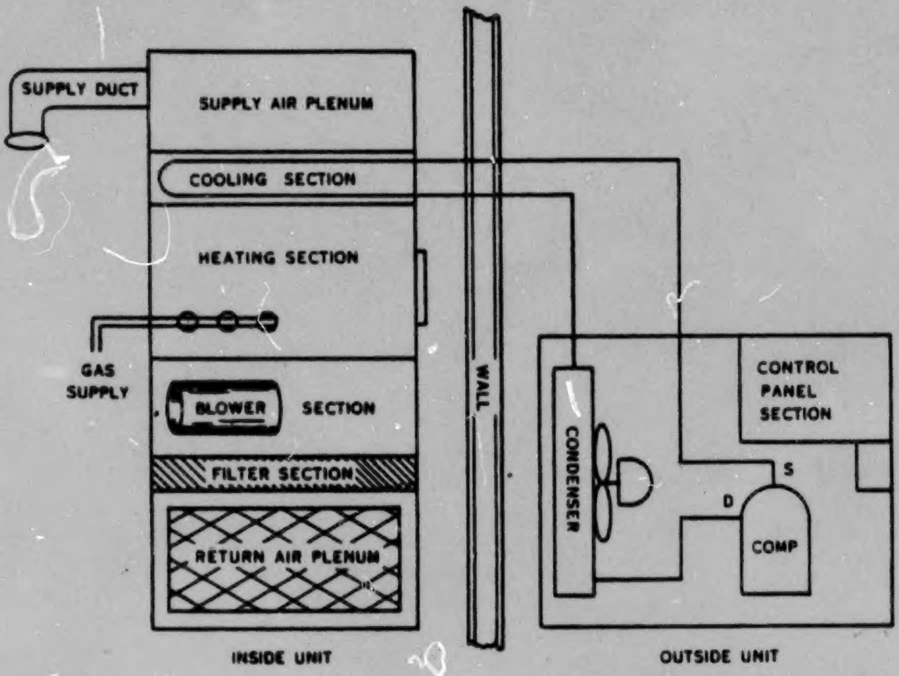

SUPPLY DUCT
SUPPLY AIR PLENUM
COOLING SECTION
HEATING SECTION
GAS SUPPLY
BLOWER
SECTION
FILTER SECTION
RETURN AIR PLENUM
WALL
CONDENSER
CONTROL PANEL SECTION
S
D
COMP
INSIDE UNIT
OUTSIDE UNIT

Figure 9. Dual System

The following are used by both heating and cooling operations.

THE RETURN PLENUM. In the return plenum, air is returned either by ducts or velocity pressure from the controlled space for reconditioning.

THE FILTER SECTION. In this section the dust, lint, and other foreign materials are filtered out of the air prior to reconditioning.

THE BLOWER SECTION. This section contains the unit used to convey the air through the active conditioning process and recirculate it back to the space being controlled.

THE HEATING OR COOLING SECTION. This is where the air is reconditioned to the desired temperature.

THE SUPPLY AIR PLENUM. In this section the reconditioned air is collected prior to being distributed into the various parts of the house or building.

THE SUPPLY DUCTS. Supply ducts are used to convey the reconditioned air to the rooms being serviced. They are normally round in construction and are insulated to prevent heat gain or heat loss between the controlled variable and the system. Each of the ducts is supplied with a balancing damper in the outlet from the plenum and a room damper in the outlet extending into the controlled space. The balancing damper is there to insure that the proper amount of air enters the controlled space to achieve the desired condition.

THE DUCT OUTLETS. Duct outlets in each room contain a grill device to uniformly distribute the pattern of airflow to achieve maximum results. There are several types of outlets, depending on the design desired for each application.

The power requirement for the furnace is 120v ac to run the blower, and this voltage is stepped down by the transformer to 26v ac for the control circuit. The air conditioner operates off of 240v ac single-phase power and 26v ac control voltage circuit.

The refrigerant used by the system is R-22.

The gas used in the furnace burners is dependent upon local gas usage. It can operate on natural or bottled gas. If the gas type is changed, the jets in the burner must be changed to accommodate the new type of gas. The trainer is using natural gas.

Heating System

The heating system consists of a gas-fired furnace rated at 100,000 Btu per hour input at the burner, and 80,000 Btu per hour output into the controlled space. See figure 10 for the component locations.

- FURNACE BODY
- GAS PRESSURE REGULATOR
- GAS VALVE
- GAS BURNER
- FAN
- FAN RELAY
- HEAT EXCHANGER
- TRANSFORMER
- FAN SWITCH
- LIMIT SWITCH
- PILOT VALVE
- FILTER

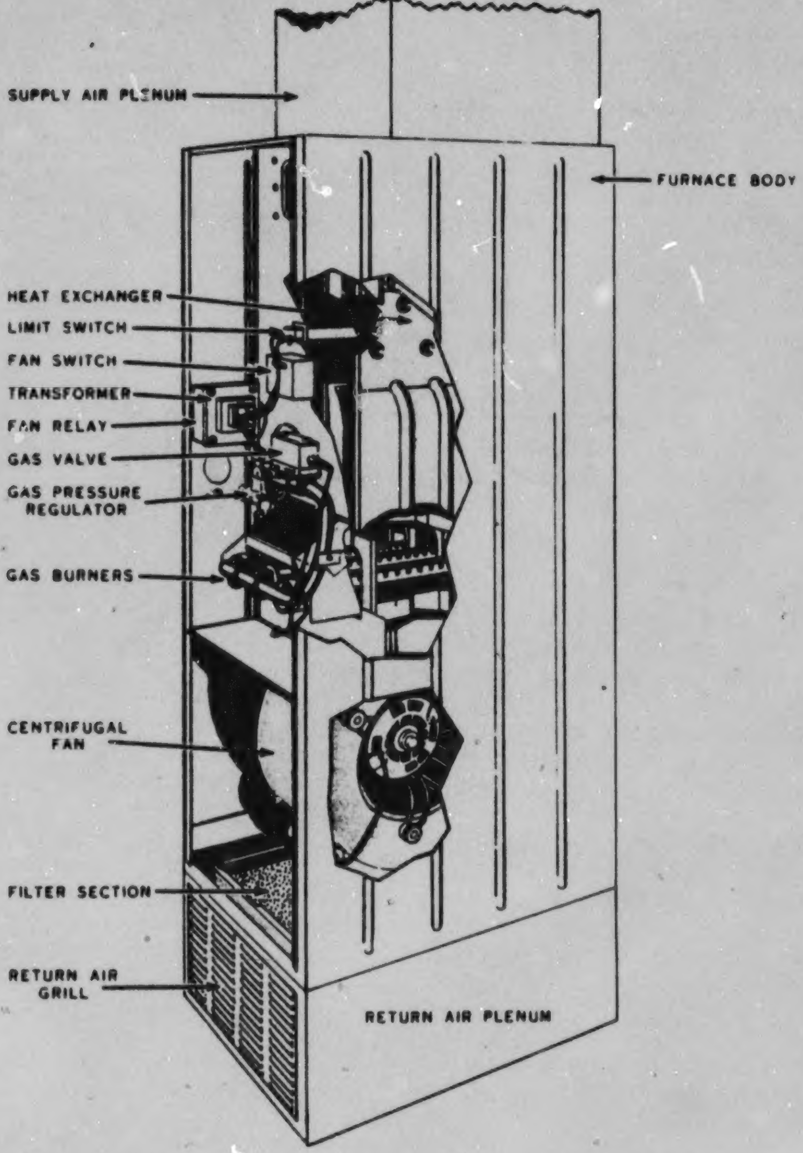

SUPPLY AIR PLENUM
FURNACE BODY
HEAT EXCHANGER
LIMIT SWITCH
FAN SWITCH
TRANSFORMER
FAN RELAY
GAS VALVE
GAS PRESSURE REGULATOR
GAS BURNERS
CENTRIFUGAL FAN
FILTER SECTION
RETURN AIR GRILL
RETURN AIR PLENUM

Figure 10. Gas-Fired Furnace

THE FURNACE BODY. It consists of the outside shell and the structural members.

THE GAS PRESSURE REGULATOR. This regulator is a diaphragm-type gas valve located in the gas inlet line. Its purpose is to supply constant gas pressure to the burners.

THE GAS VALVE. The gas valve is a two-position solenoid valve and is used to control the flow of gas to the burners.

THE GAS BURNERS. The burners are composed of cast iron with several holes or outlets evenly distributed along their length. The majority of gas burners are the Bunsen type and operate with a nonluminous flame. The air supply must be adjusted so that all of the gas is consumed in the combustion chamber. Unburned gas causes carbon deposits to clog up the heat exchanger.

THE FAN. It is of the centrifugal forward curved type and draws air from the return plenum forcing it through the heat exchanger and out the ducts to each room.

THE HEAT EXCHANGER. The heat exchanger consists of two completely separate sections. The fire is produced in one section and the conditioned air is passed through the other section.

THE TRANSFORMER. The transformer has a primary voltage of 120v ac and a secondary voltage of 26v ac and a capacity rating of 40v amps. It supplies the control circuit for both the cooling and heating cycle.

THE FAN SWITCH. The fan switch is used during the HEATING CYCLE ONLY. The switch has a bimetal element that closes on a rise in the temperature. The bimetal element is extended into the heat exchanger to sense the temperature changes and cycle the blower fan.

THE LIMIT SWITCH. This switch is a high temperature safety device. If the temperature inside the heat exchanger exceeds 200°F, the limit switch will open and cause the gas valve to close stopping the burner flame.

THE PILOT LIGHT. There are two types of flame safety devices activated by the pilot light flame. They are the thermocouple and thermopile. When the thermocouple is heated by the pilot flame, the thermocouple produces millivolts that energize a magnet coil in the pilotstat. With the thermopile, the millivolts produced provide the current, in series, to the gas burner control circuit. If the pilot light goes out, the circuit to the gas valve is permanently opened and cannot be reclosed until the pilot is reignited. The furnace wiring diagram is shown in figure 11.

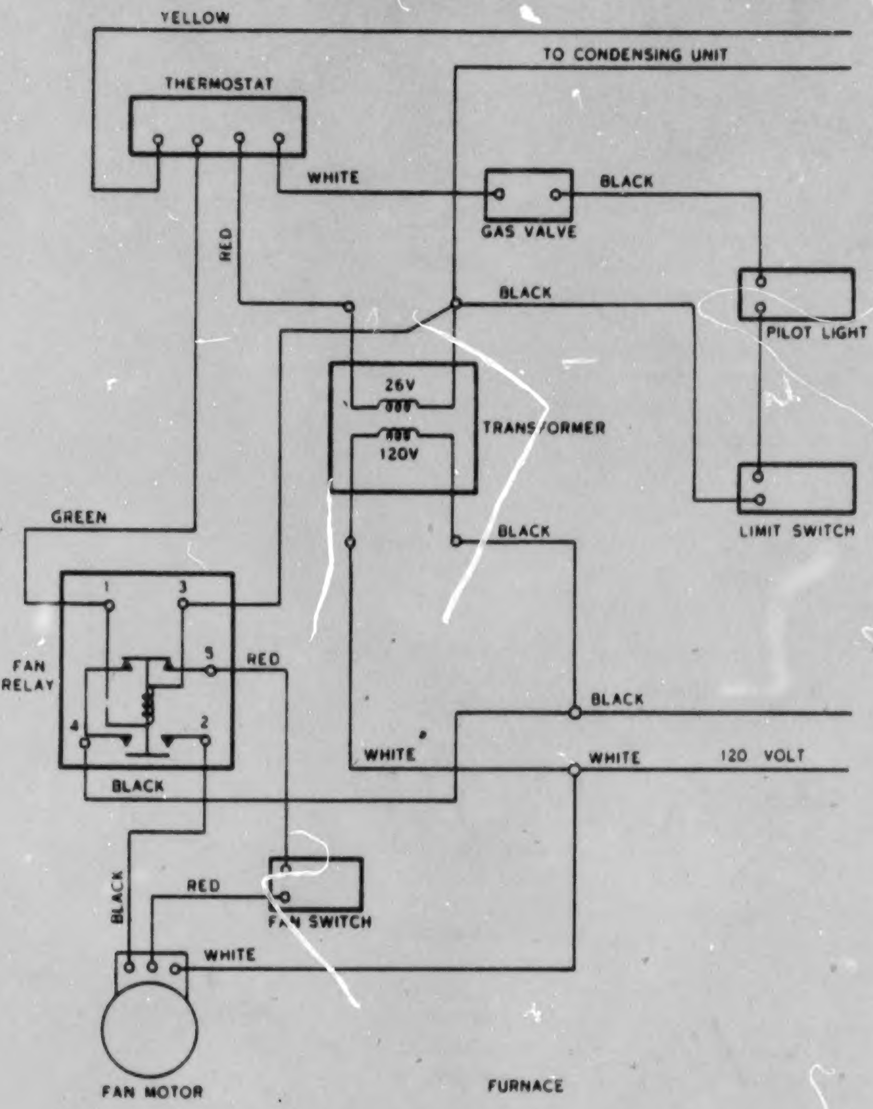

YELLOW
TO CONDENSING UNIT
THERMOSTAT
WHITE
BLACK
GAS VALVE
RED
BLACK
PILOT LIGHT
26V
TRANSFORMER
120V
LIMIT SWITCH
GREEN
BLACK
1
3
FAN RELAY
5
RED
4
2
BLACK
WHITE
BLACK
WHITE
120 VOLT
BLACK
RED
FAN SWITCH
WHITE
FAN MOTOR
FURNACE

Figure 11. Furnace Wiring Diagram

Cooling System

The cooling system consists of an electrical air-conditioning unit. The trainer is a Carrier Model 28 GB4300. It has a 38,000 Btu capacity. This size unit is adaptable to Capehart or Wherry housing units found on most bases. It can adequately cool a floor space of 1500 to 1800 square feet. This figure is derived from the general rule of thumb, used with smaller air-conditioning systems, that one ton of refrigeration effect will cool 600 square feet. The air conditioner is divided into two major sections. The condensing section is mounted outside of the house on a concrete slab, and the evaporator section is mounted in the supply air plenum above the furnace body.

The condensing unit is really very simple in makeup and resembles a window unit in construction, except that the evaporator isn't inside the unit body. Components contained in the condensing unit are: condenser coil, compressor, condenser fan and fan unit controls, wiring and tubing. The evaporator section consists of the evaporator coil and the TEV or capillary tube, depending on the type of metering device required by the unit.

The compressor contains a high-speed hermetically sealed motor and is very efficient if all proper procedures and precautions are followed. A crankcase heater is installed around the compressor body to keep the oil warm, thus, keeping the liquid refrigerant boiled out of the oil at all times. The heater is connected directly to the power circuit and is in operation at all times. If the current flow to the heater is interrupted, the oil must be reheated the same length of time as the interruption, up to 12 hours. The heater must be operated 12 hours prior to startup of the system, following shutdown. No more than 12 hours are required to heat the oil at any time.

All of the controls are located in the control panel on the condensing unit. By removing the control panel cover, it is possible to see everything but the condenser and fan.

The unit is equipped with a step-down transformer, but, in this application it is not used. The control voltage is drawn from the transformer of the furnace. The same circuit is wired in series with the dual-purpose thermostat.

Heating and Cooling Thermostats (Low Voltage)

Think for a minute. How many thermostats have you studied during this course? They all serve the same purpose, to control the temperature range of the controlled variable. The thermostat that you will study during this area of instruction is the dual-purpose, low-voltage, heating-cooling thermostat as used in domestic applications.

Low-voltage thermostats operate on 24 or 26v ac depending on the current load and type of transformer used. In homes, wired for 110v ac, the 24v ac thermostat is used. Newer homes, wired for 115-120v ac, provide the thermostat with 26v ac. There are several styles of thermostats; the one most commonly used is the type which places the contactors in a sealed glass bulb containing mercury, see figure 12. The bulb is attached to the sensing device, normally a bimetal coil; and the bulb tilts in response to the change in the controlled variable.

Anticipators

Since low voltage temperature thermostats are operated solely by mechanical action, they are not too sensitive. This results in wide temperature variations in the controlled space, in both the heating and cooling cycles of the system. To compensate for the mechanical action and to increase the sensitivity of the instrument, a device known as an anticipator is added to the thermostat.

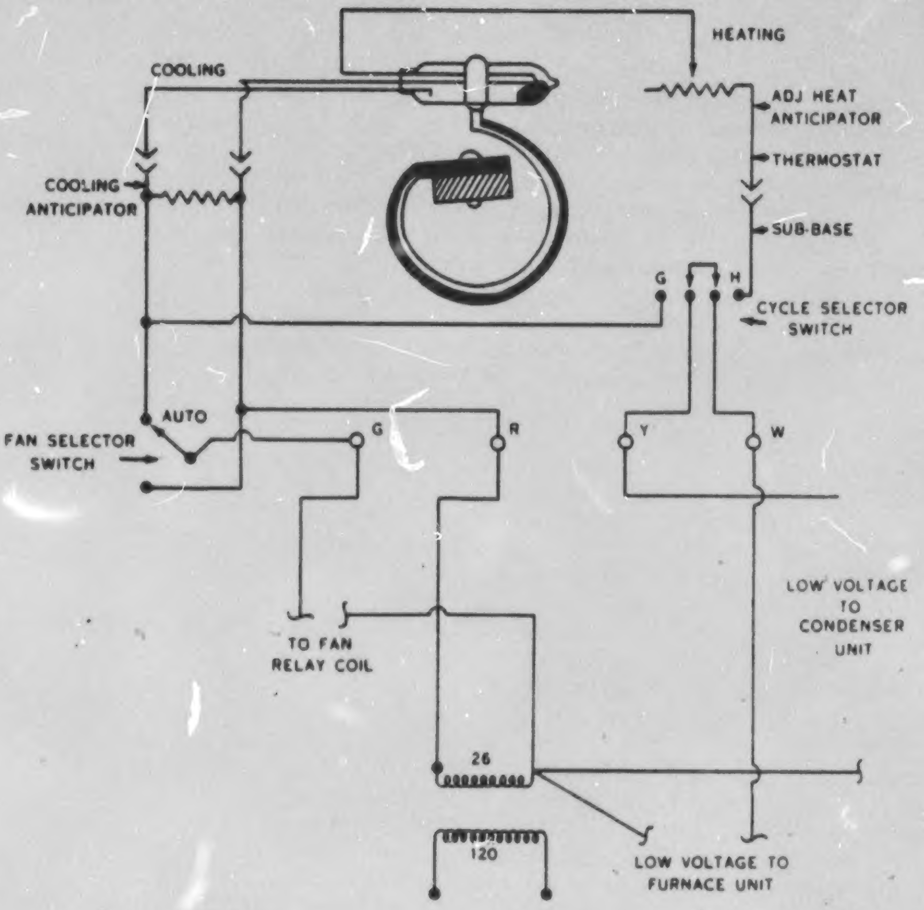

HEATING
COOLING
ADJ HEAT ANTICIPATOR
THERMOSTAT
COOLING ANTICIPATOR
SUB-BASE
G
H
CYCLE SELECTOR SWITCH
AUTO
FAN SELECTOR SWITCH
G
R
Y
W
LOW VOLTAGE TO CONDENSER UNIT
TO FAN RELAY COIL
26
120
LOW VOLTAGE TO FURNACE UNIT

Figure 12. Low-Voltage Thermostat Wiring Schematic

HEATING ANTICIPATORS. These anticipators generate a small amount of heat inside the thermostat during the heating cycle. The bimetal element senses two heat sources; the room temperature change, and the temperature change emitted by the anticipator. This causes the circuit to be broken a few moments before the room temperature is reached, closing the gas valve and shutting off the burners in the furnace. Then the remaining heat in the heat exchanger is discharged into the room which raises the temperature to set point. When the thermostat calls for heat, the gas valve will again open and the burner will ignite repeating the cycle until enough heat is produced to satisfy the thermostat. With the incorporation of the anticipator, the undesirable condition of wide temperature variations between cycles is eliminated. The anticipator can contain the room temperature to ± 3°F differential making them much more sensitive than older models of the thermostats on the market.

Heating anticipators are normally adjustable. Adjustment is generally accomplished by placing the wiper arm at the correct resistance value. If you know the current draw of the gas valve, set the wiper arm at that point. If the current draw is unknown, use a very sensitive ammeter and determine the amperage draw. If the anticipator has to be adjusted by trial and error, move the arm one direction; and, if short cycling occurs, move it in the other direction a little at a time until satisfactory results are obtained.

THE COOLING ANTICIPATOR. The cooling anticipator appears as a fixed resistor in the thermostat subbase. The anticipation function is the reverse for the cooling cycle as it is for the heating cycle. The cooling anticipator is active only during the OFF cycle, and it is wired in the thermostat circuit in parallel with the power source (see figure 12). During the off cycle, the points in the contactor are open, so current taking the path of least resistance will divert through the anticipator and produce a minute amount of heat which is sensed by the bimetal coil in conjunction with the rise in the room temperature. This small amount of heat causes the thermostat to react prior to the temperature in controlled space getting too warm, thus allowing the temperature differential to be within ± 3°F.

Remember, the heating anticipator is wired in series with the control circuit, and the cooling anticipator is wired in parallel with the points of the thermostat.

THERMOSTAT SUBBASE. The dual-purpose thermostat has two major components; the thermostat and the subbase. The subbase serves as a receptacle for the wiring and the cooling anticipator.

Installation Requirements. Thermostats should be mounted on a solid inside wall approximately four to five feet above the floor. There should be conditioned space on both sides of the wall. The wall must not contain hot or cold pipes, air ducts, or chimneys. The thermostat must be installed where it will not be affected by drafts from outside doors, or heat rays from the sun or appliances. The airflow, preferably the return air, should be sensed by the thermostat.

DO NOT ATTEMPT TO REPAIR A THERMOSTAT: REPLACE IT IF IT FAILS. The time spent finding parts and the labor consumption involved in the repair of a thermostat would cost more than the new thermostat.

The furnace wiring diagram as shown in figure 13 includes the thermostat and subbase wiring.

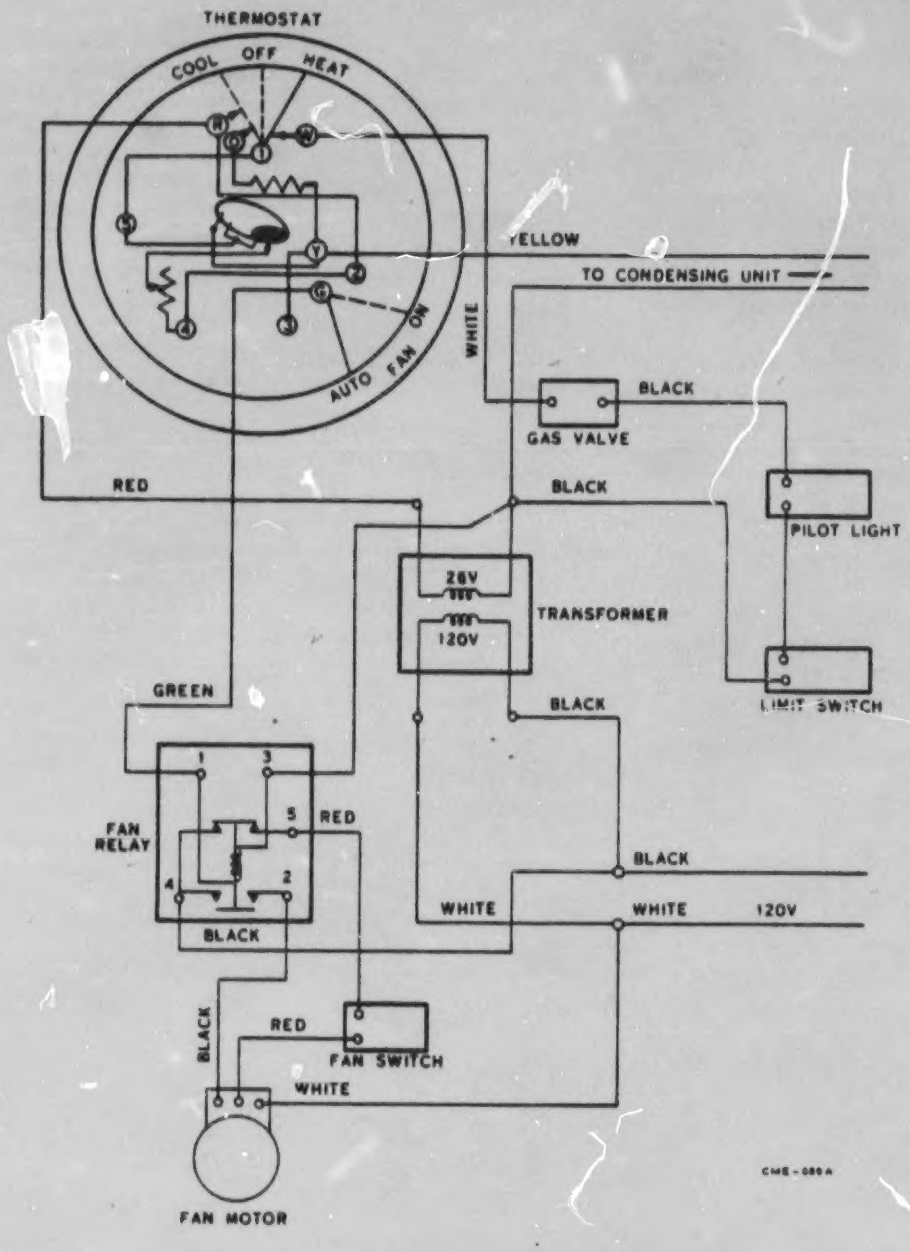

THERMOSTAT
COOL
OFF
HEAT
R
W
O
Y
G
AUTO
FAN
ON
YELLOW
TO CONDENSING UNIT
WHITE
BLACK
GAS VALVE
RED
BLACK
PILOT LIGHT
24V
120V
TRANSFORMER
LIMIT SWITCH
GREEN
BLACK
1
3
5
RED
FAN RELAY
4
2
BLACK
BLACK
WHITE
WHITE
120V
BLACK
RED
FAN SWITCH
WHITE
FAN MOTOR
CME-080A

Figure 13. Furnace Wiring Diagram

QUESTIONS

1. Define air conditioning.
2. List four uses of air-conditioning equipment.
3. List three types of air-conditioning systems identified in this study guide.
4. What type of condenser is used on the residential unit, window unit?
5. What are the two most common types of metering devices used for air conditioning?
6. What is the purpose of insulation?
7. Name the six types of insulation.
8. In regard to air conditioning, what is the prime reason asbestos would be used and to insulate what?
9. Why is styrofoam such an effective insulation?
10. What is the most flammable insulation discussed in this study guide?
11. What three applications are fans used for?
12. Name the two fan classifications.
13. Name the three axial flow fans.
14. Name the three radial flow fan blade types.
15. What is the normal evaporator temperature of an air-conditioning coil designed to maintain?
16. Why is a centrifugal blower preferable to an axial flow fan?
17. Name the controls used to maintain temperature.
18. Humidistats are devices operated by ________________, ______________________, or ______________________.
19. Name the pressure controls used to safely operate a system. ________________, ________________________, __________________________.
20. How are filters classified?
21. What is meant by filter media?
22. What is a viscous media filter?
23. Describe the principle of operation of an electronic air cleaner.

24. What use does ultraviolet light serve as an air purification device?

25. A filter in the intake or return plenum of a system containing carbon granules would be used to control ______________________________.

26. Name seven components identified in the dual system of the residential heating and cooling systems.

27. Name 10 components identified on the gas-fired furnace.

28. What part of the circuit does each of the following terminals of the low-voltage thermostat control?

yellow ________________ red ________________

green ________________ white ________________

REFERENCES

1. AFM 85-18, Maintenance and Operation of Refrigeration, Air Conditioning and Evaporative Cooling and Mechanical Ventilating Systems
2. Textbook, Trane Air Conditioning Manual
3. Textbook, Air Conditioning, Delmar
4. Textbook, Modern Refrigeration and Air Conditioning, Althouse, Turnquist and Bracciano

AIR FLOW INSTRUMENTS

OBJECTIVE

This study guide will acquaint you with the various types of air measuring instruments, how to measure the rate of airflow, and how to determine the velocity of air.

INTRODUCTION

One of the functions of an air-conditioning system is to deliver the proper amount of air to an area at a specific time. It is the air-conditioning specialist's job to know if the system is producing properly. There are several instruments on the market that will measure the velocity of the air. We will measure the velocity of the air using some of these instruments. There are two basic factors that determine the amount of airflow. The velocity or rate of air movement and the area that it must pass through. When talking about velocity we use the term "feet per minute (fpm)."

AIR MEASURING INSTRUMENTS

There are three types of instruments commonly used in the field. These are the anemometer, inclined manometer, and velometer. All of these instruments are employed to measure the velocity in fpm of airflow. Readings can be taken at the following locations: Return Air duct, Supply Air duct, outside air duct, or inside the duct system.

Anemometer

The anemometer is an instrument used to measure air velocity in linear feet. This meter is composed of the fan housing, three dial faces, and the propeller which moves at the rate of the air speed turning a gear mechanism which operates the dials. There is an engaging lever and a reset lever on top of the dial face.

In using the anemometer, we normally take readings at the duct face. The face should be divided into equal 6" squares. If the duct measured 24" x 18", then there would be four 6" squares across the length, and three 6" squares across the height, or a total of (4 x 3 = 12) equal 6" squares of surface area (see figure 14).

At each of these six-inch openings, the anemometer will be used for 10 seconds. The resulting time lapse for the total measurement is expressed as elapsed time and is obtained by multiplying the number of equal 6" squares by ten. For example: 12 x 10 = 120 seconds.

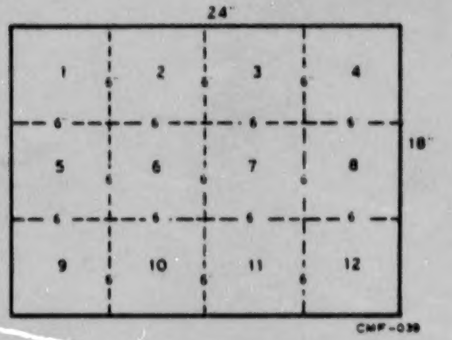


Figure 14.Calculating Du[illegible]urface Area

To operate the anemometer, place the instrument into the stream of air being measured. Before starting, check to be sure that your hands are cupped around the meter in such a way to prevent obstructing the airflow through the meter. Allow the propeller to reach maximum speed, then trip the engaging lever and hold it in the same location for 10 seconds, then move to the next area(s) until all of the 6" areas have been measured and trip the lever to the OFF position.

In reading the anemometer, suppose you held the instrument in the airstream for 120 seconds. The reading on the dials would read in the following sequence:

1. Left dial reading
2. Right dial reading
3. Center dial reading

If the indicator on the two smaller dials is between any two numbers, take the reading of the lesser number and read the large dial exactly as indicated (see figure 15).

In figure 15, the left dial reading would be 8000, the right dial reading would be 300, and the center dial reading would be 80. Therefore combining the numbers into proper sequence, the resulting anemometer reading would be 8380.

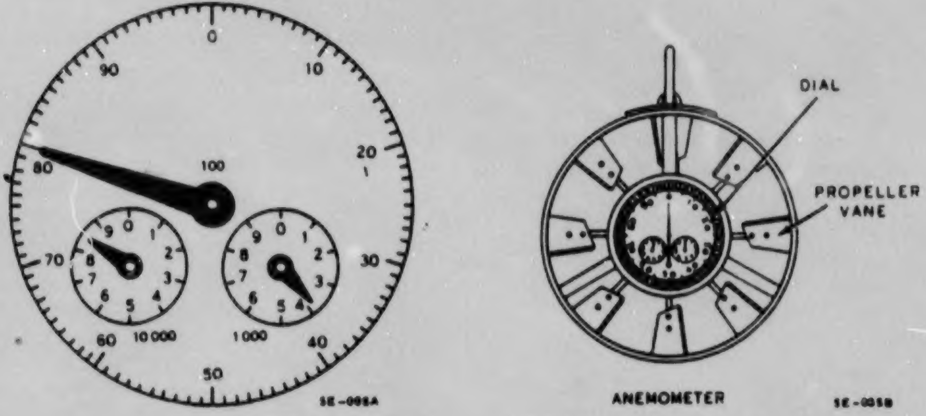


Figure 15. Anemometer Reading (AR)

The following formula is used to convert the anemometer reading to fpm velocity:

$$\text{fpm} = \frac{\text{Anemometer Reading (AR)} \times 60}{\text{Elapsed Time (ET)}}$$

To figure the fpm of our sample problem, the answer would be

$$\text{fpm} = \frac{\text{AR} \times 60}{\text{ET}} \text{ or } \frac{8380 \times 60}{120} = \frac{8380}{2} = 4190 \text{ fpm}$$

Inclined Manometer

The manometer family of air measuring instruments contains various types and styles; however we will limit the study of manometers to one type, the inclined manometer. The manometer is used to measure the pressure of air in inches of water. Within the duct system we find two predominant pressures, static and velocity. Static pressure is the outward pressure of air in all directions. Velocity pressure is the force exerted by the movement of air in the direction of flow. Often it is impossible to get the manometer into the airstream to measure the pressure, so the pitot tube was developed to allow access to the internal sections of the duct in hard-to-get-to areas. In reality the pitot tube is a tube within a tube as indicated in figure 16.

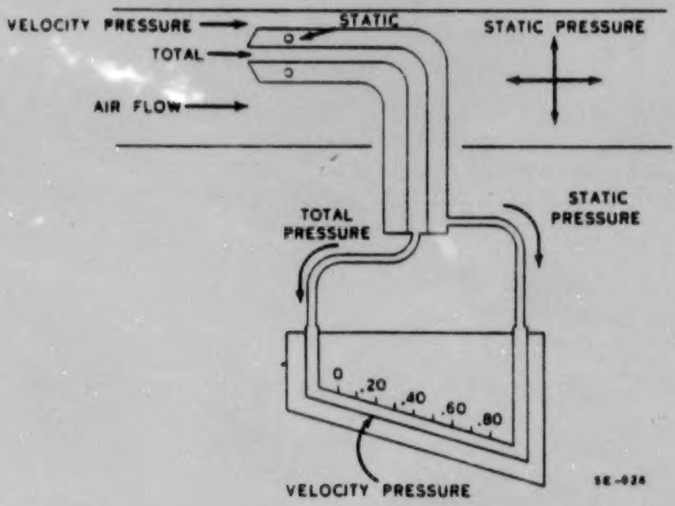


Figure 16. Pitot Tube and Manometer Installed

The pitot tube is inserted into the airstream and velocity pressure goes into the center of the assembly to the manometer, forcing the oil column in the meter downward. The static pressure enters the small ports surrounding the tube to the manometer forcing the column of oil in the meter tube upward. The velocity reading is taken on the adjustable scale where the oil level stabilizes.

The pressure indicated on the manometer is known as pressure of velocity. It is represented as PV in the conversion formula used to convert pressure into feet per minute. To convert pressure of velocity into fpm, the following formulas will be applied:

$$\text{fpm} = \sqrt{PV} \times 4005$$

fpm - the number of feet of air which will pass through a duct area in one minute

$\sqrt{}$ - symbolizes square root

PV - pressure of velocity as read on the inclined manometer

X - multiplied by

4005 - is a constant and is based on the velocity of standard air.

Now, let's see how the formula works. Assume the velocity pressure reading of .25 has been obtained with the manometer.

$$\text{fpm} = \sqrt{.25} \times 4005 = .5 \times 4005 = 2002.5$$

Velometer

The velometer is a rugged mechanical system, soundly engineered for very concise readings. Inside the meter, air impinges on an aluminum vane moving the pointer. This vane travels in a calibrated air chamber or tunnel constructed to be airtight to provide a desirable scale distribution. The moving system is balanced by counterweights to provide accuracy in all positions. The moving system is equipped with bronze hairsprings and moves on monel pivots which ride in sapphire jewel bearings. Some velometers are equipped with filters to protect them from extreme dust conditions. When a filter is supplied with the instrument, the filter is an integral part of the instrument and must be used. If the filter is left out, the instrument will give a false reading.

To measure velocities at supply openings, attach the proper jet by means of the appropriate tube and tube fittings. To determine the average velocity mentally divide the opening into a number of equal areas. Take a reading at each of the areas and average the readings. There is no exact rule for the exact number of readings that must be taken, but the more that are taken, the more accurate the average, and it is recommended that a minimum of six readings be used.

To measure the air velocity at the suction opening, connect the proper jet by means of the tube and tube fittings to the right-hand port of the meter. While taking the readings, hold the jet so that it is perpendicular and the tip is in the same plane as the opening. This is very important because the velocity changes very fast in front of a suction opening. To measure velocities inside of ducts, use the duct jet called for in the manual of instructions. The duct jet should be inserted into the left-hand port. Read the scale marked with the same number of jet being used.

Calculating Cubic Feet per Minute (cfm)

After establishing the fpm, the cfm can be established using the formula:

$$\text{cfm} = \text{fpm} \times \text{duct area (sq ft)}$$

Once the cfm has been established, we can calculate the pounds of air changed per minute in the space being considered.

$$\text{lbs of air} = \frac{\text{cfm}}{\text{specific volume}} \text{ or cfm} \times \text{specific density}$$

NOTE: Remember if no means is provided for finding specific volume, use the value for standard air which is 13.5 cu. ft. Specific density for standard air is .075.

BALANCING AIR-CONDITIONING SYSTEMS

Air-conditioning systems are designed to condition the air within the system and then to distribute this treated air to the proper place, in the proper amounts, and with the least possible annoyance to the consumer of the conditioned air.

Use of Air

In air-conditioning practice, as air is passed through the unit, it is heated or cooled, humidified or dehumidified, cleaned, and then distributed to places where it is needed. An air-conditioning unit, regardless of its efficiency, and its size, would be handicapped if the air could not be properly distributed. It is important that the air distribution be accurately proportioned to the need and adapted to the apparatus in which it is to be used. The distributed air must be clean, provide the proper amount of ventilation, and must carry enough heat to keep the conditioned space warm or must be able to absorb enough heat to cool the conditioned spaces.

Stratification of Air

Air in an occupied space must be kept moving, or stagnation or stratification results. Warm air tends to rise, cold air tends to settle. In a room where the air is not deliberately moved, the air will assume levels according to temperature.

It is important to locate all automatic thermostats and humidistats at the proper level because of this stratification. Also, stratification tends to make smoke haze hover in layers.

Unfortunately, some grilles are so located that the air will be moved only in certain parts of the room and the air will become stagnant in other parts of the room. There is also the problem of the obstruction to the air movement caused by the furnishings of the room. For this reason, and to enable higher grille velocities, some grilles are located high in the room (6 feet or more), and some are located in the ceilings. These high grille locations necessitate that the grilles be attractive in appearance or concealed. This is called a diffusion grill because its design promotes mixing of some of the room air with the entering air.

Air Ducts

To deliver air to the conditioned space, air carriers are needed. These carriers are called ducts. The ducts are made of sheet metal or some nomcombustible structural material.

The ducts work on the principle of air pressure difference. If a pressure difference exists, air will move from the higher pressure to the area of lower pressure. The greater the pressure difference, the faster the air will flow.

Two shapes of ducts commonly used for carrying air are: (1) round duct, (2) square or rectangular duct. The round duct is the more efficient based on volume of air handled per perimeter distance (distance around). That is, less duct material is needed to make a large enough duct to carry the necessary air.

The square or rectangular duct harmonizes with building construction and fits into walls and ceilings better than round ducts. It is easier to install rectangular ducts between joists and studs.

Ducts Sizes

To determine the size duct that should be used to carry air to a room, it is necessary to first find the volume of air that is to be delivered to the room.

This volume of air depends on the amount of heat the air must deliver to the room during the heating season, or the amount of heat to be removed during the cooling season.

Determining Air Quantities

To determine the proper air quantities to each room there are certain things that must be known:

1. Specific heat of air
2. Weight of air
3. Temperature difference between supply and room temperature
4. Total Btu's of the conditioned space

The specific heat of air is the amount of heat required or released to change the temperature of one pound of air 1°F. The specific heat of air is .24 Btu's/Lb/Deg. F.

The weight of air is derived from the definition of standard air, which is one pound of dry air at 70°F, which occupies 13.34 cubic feet, one cubic foot has a specific density (weight) of .075 at atmospheric pressure of 14.7 psia or 0 gage, at sea level.

Now that we know what the specific heat of air and the specific density or weight of standard air is, we can compute the CFM required for each room by using the formula:

$$\text{CFM} = \frac{\text{Room Heat Load}}{1.08 \text{ X TD}} \text{ (Btu's/HR)}$$

Room load will be found during heat load estimating, normally done by engineers. The temperature difference (TD) would depend on the design conditions. The 1.08 is derived from multiplying the weight of one cubic foot of standard air (.075) times the specific heat of air (.24). This will give you the amount of heat the air is capable of absorbing in one minute. We then multiply this times the number of minutes in one hour (60), which gives us our 1.08, the heat absorbing capability of air in one hour. Then by multiplying times our design temperature difference then dividing into our room load will give us our Cubic Feet Per Minute (CFM) required to maintain desired room temperatures.

SUMMARY

Air velocity can be measured with an anemometer, manometer, or velometer. After velocity is known, it is a simple matter to determine the cfm and pounds per minute of air being changed in the space involved.

QUESTIONS

1. What does the anemometer read?
2. Write the following equations for the Anemometer, Velometer, and Manometer.
    a. fpm =
    b. cfm =
3. A duct opening measures 36" by 48", what is the ET when using an anemometer?
4. When is a pitot tube used with a manometer?
5. What is velocity pressure?
6. What is static pressure?
7. On a velometer equipped with a filter, what would occur if the filter were not used?
8. If air in a conditioned space is not kept moving what may occur?
9. Air ducts work on what principle?
10. What are the two most common duct designs?
11. What is meant by specific heat of air?
12. In the formula for determining CFM in airflow balancing what does the 1.08 represent?

REFERENCES

1. Textbook, Trane Air Conditioning Manual
2. Textbook, Air Conditioning, Delmar
3. Textbook, Modern Refrigeration and Air Conditioning, Althouse, Turnquist, and Bracciano

PSYCHROMETRICS

OBJECTIVE

This study guide and related material will aid you in gaining knowledge of psychrometrics as related to air conditioning and will provide practical experience in the use of the psychrometric chart.

INTRODUCTION

For the air-conditioning specialist to properly analyze his equipment he should know about the conditions that he is trying to control. Since air is the prime medium used to cool or heat the controlled space, it stands to reason the specialist should be well aware of the air that he is trying to control. This is done by an analysis of the conditions and properties that air contains.

PSYCHROMETRICS

Air is the primary medium that is used to control the conditions in the controlled space. Air can be used to control the humidity and temperature for three general uses: personnel or comfort cooling, equipment cooling, and process cooling. New applications for air conditioning are continually being found.

The purpose of air conditioning is to control temperature, humidity, and the circulation of the air.

The field of psychrometric study is a breakdown of the various properties contained in the air and a graphic analysis of the air conditions. If the specialist understands all he can about the air being used, the understanding of the equipment operation becomes more realistic.

Psychrometrics is defined as the study of air and its related properties. As you know, air contains some moisture (humidity). However, let us consider the other properties relating to graphic analysis of moisture-laden air. Air is a mixture of highly superheated gases. About 78 percent of the air is nitrogen, 21 percent oxygen, and the remaining one percent is composed of minute quantities of other gases such as carbon dioxide, argon, neon, ozone, hydrogen, helium, and krypton. All of these form the air that we breathe, and use for air conditioning. Air exerts a force of 14.7 psia on the surface of the earth at sea level. Air and water vapors are mixed, occupying the same space and following Dalton's law of partial pressures, "The pressure of a mixture is the sum of the partial pressures of the constituent gases..." Vapor pressures are regulated by the movement of the molecules at the surface of the substance. For example, water at a temperature of 212° F has a vapor pressure of 14.7 psia.

Temperature of the Air

Temperature is the measurable heat contained in a volume of air, read in degrees. It can be expressed as degrees Fahrenheit or Centigrade, depending on the scale being used. In the psychrometric analysis such temperatures as dry bulb, wet bulb, dewpoint, saturation, and apparatus dewpoint temperatures will be considered.

Humidity of the Air

Humidity is the moisture vapor contained in the air. There is, generally speaking, two humidity expressions: specific humidity is the actual moisture contained in the air or the grains of moisture content; the relative humidity is an expression of the specific humidity in relation to the volume.

Heat Content of the Air

This term refers to the heat contained in a given condition of air. It is measured in British thermal units (Btu). It is also expressed as the enthalpy. Remember, that a Btu is the amount of heat required to raise the temperature of one pound of water one degree Fahrenheit. Based on this standard are other standards such as one ton of refrigeration. We know that it will take one ton of ice 24 hours to change from 32°F ice to 32°F water, and that it will absorb 288,000 Btu during that time. This means that Btu were absorbed at the rate of 12,000/hr, 200/min, or 3.33/sec. Any of these values means one ton of refrigeration.

Volume of the Air

Air, as any substance, must occupy space. This space is volume, and is expressed in cubic feet. The volume of air will vary with the heat contained in the air. As the temperature increases so does the volume, provided room for expansion exists. If there is no room for expansion, the pressure will increase due to the limitations imposed by the containing device.

In the case of unconfined air, the pressure remains constant. The air volume changes with the heat content. A volume of air contracts or expands 1/460 of its volume at 0°F for each degree of temperature change. If absolute zero (-460°F) was reached, the volume would shrink to zero as well. Although this is strictly theoretical and has never been achieved, it does point out the relationship of temperature to volume. Specific volume is the number of cubic feet of air that it takes to weigh one pound.

Weight of the Air

If the air has all of the foregoing properties, then it must be concluded that it has weight. This weight is referred to as specific density. The psychrometric chart will provide the basis for computing the density. The specific volume is known as cubic feet of air per pound of dry air. The weight of the air is dependent on the amount of moisture contained in the air and we will use the constant of one (1) which is divided by the specific volume obtained from the chart. If the S. V. is 13.5 cu ft then the S. D. will be .075.

$$\begin{array}{r} .075 \\ 13.5\overline{)1.} \end{array}$$

It can be noted that as the specific volume increases, the density of the air will decrease.

Psychrometric Chart

The chart is the tool used to analyze the relationship of the properties of the air. The specialist should master at least the meaning of the chart in order to properly understand the air that is being conditioned.

The relationships of the properties of the air are graphically illustrated on the psychrometric chart as a series of lines and curves that have been scientifically formulated to show the whole picture of the air being studied.

The comparison of the lines and curves at intersecting points of the scales on the chart gives us a very comprehensive analysis of the air being studied. More than one condition may appear on the chart to give us more accurate analysis and true operation of the system in consideration.

Sling Psychrometer

The sling psychrometer is the instrument that is most often used to obtain the basic values needed to work a psychrometric problem. The sling psychrometer (see figure 17) is an instrument that is very basic in design and operation. There are two standard thermometers mounted on a holder with provisions for the device to be whirled in the air. One of the thermometers has a sock attached to the bulb, which is moistened in distilled water prior to slinging of the instrument. The slinging of the instrument will pick up two temperatures. One is ambient or dry bulb temperature; the second, wet bulb temperature.

The operation of the psychrometer is very simple. The wet bulb sock is saturated with distilled water (because there are no mineral deposits in the water that will form residual scale deposits following evaporation). Then the instrument is whirled in front of the individual for about 30 seconds, read and then whirled for another 15-30 seconds and read a second time.

During this process air passing through the sock causes evaporation. The evaporation will cool the temperature of the wet bulb thermometer below the dry bulb temperature, depending on the amount of moisture that is in the air being measured. The drier the air, the higher the evaporation rate. The second reading helps insure that the maximum evaporation rate was attained.

The difference between wet bulb temperature and dry bulb temperature is known as wet bulb depression.

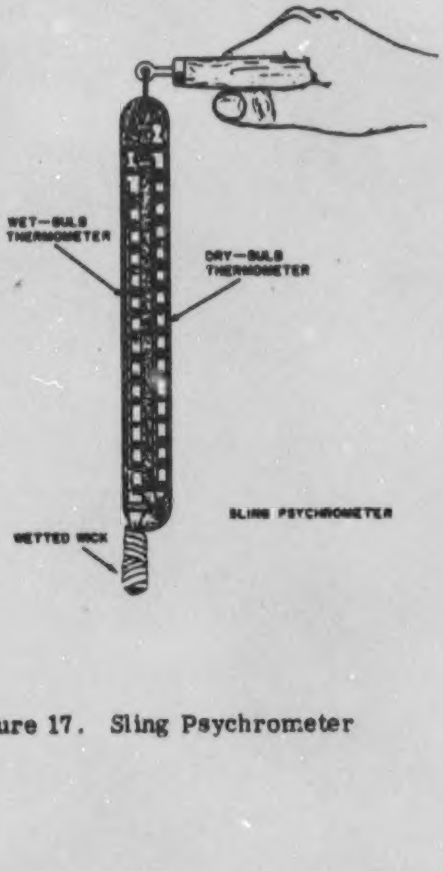


Figure 17. Sling Psychrometer

Psychrometric Chart Scales

Once the dry bulb temperature and wet bulb temperature have been obtained, we can then begin the plotting procedure. In order to know what we are doing, the scales that are read on the psychrometric chart are the first point of identification on the chart. The psychrometric chart contains lines and curves which have corresponding scales and are read at intersecting points.

In figure 18, the lines and scales are identified, then the later figures that accompany the terms and definitions will point out the names of the lines corresponding to each set of scales. There are basically five sets of scales that are used on the psychrometric chart. Some of the readings will be scale differential readings.

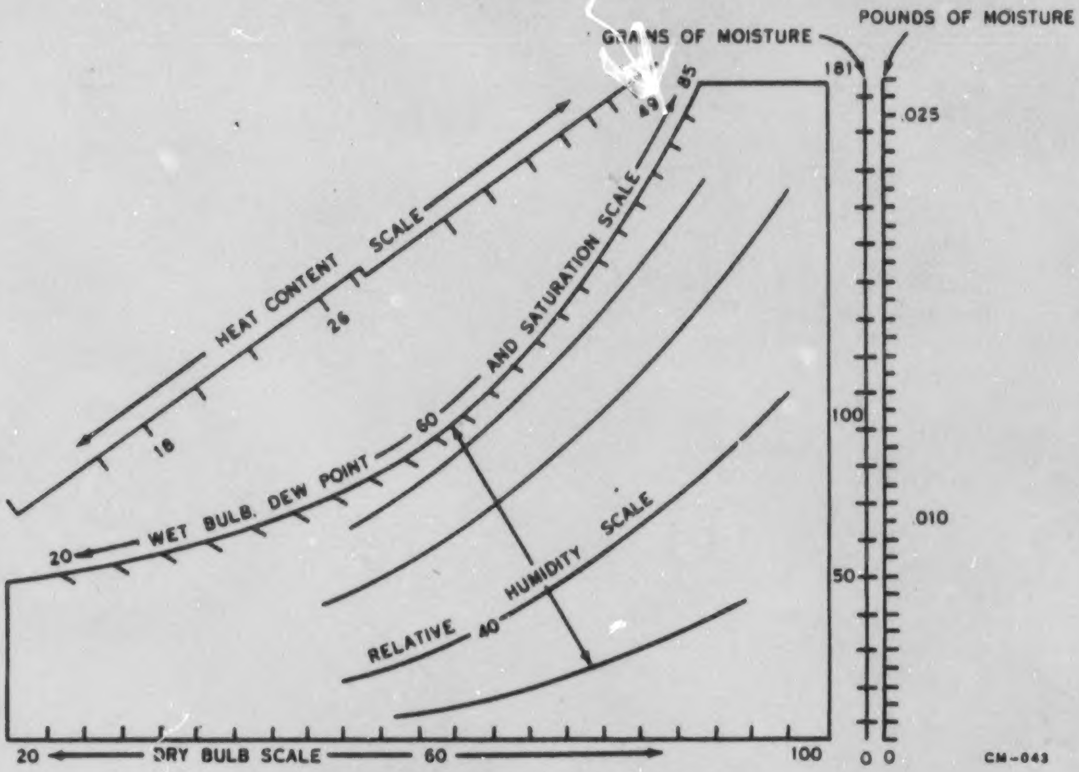

GRAINS OF MOISTURE
POUNDS OF MOISTURE
181
.025
85
49
HEAT CONTENT SCALE
26
18
WET BULB. DEW POINT AND SATURATION SCALE
60
20
RELATIVE HUMIDITY SCALE
40
100
.010
50
20 DRY BULB SCALE 60 100
0 0
CM-043

Figure 18. Psychrometric Chart Scales

414

Dry Bulb Temperature (D B)

Dry bulb temperature is the ambient air temperature read on a standard thermometer. Dry bulb plots will appear on the vertical lines of the chart which correspond to the dry bulb scale located along the bottom of the graph. Dry bulb is plotted by locating the indicated condition on the scale, and drawing a vertical line corresponding to the temperature value as shown by the heavy line in figure 19.

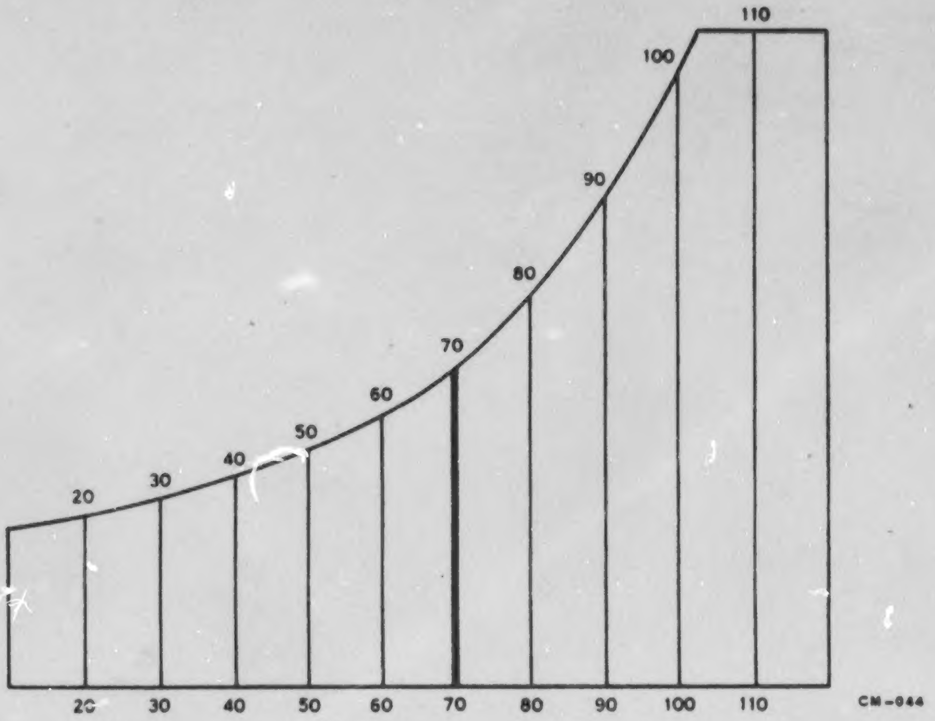


Figure 19. Dry Bulb Line

Figure 19 is a representative sketch of the dry bulb temperature portion of a psychrometric chart. A complete psychrometric chart has a vertical line for each degree of temperature. Usually, every fifth line is numbered with its corresponding temperature. The common range for a psychrometric chart is from about 20°F to 105°F. This type of arrangement makes it simple to plot any dry bulb temperature on the chart to the nearest degree. The remaining figures in this series are also sketches and do not include all the lines on the psychrometric chart.

Wet Bulb Temperature (W B)

Wet bulb temperature is the temperature at which air ceases to be cooled by the process of evaporation. Wet bulb temperature is determined by the sling psychrometer previously described in this section. Keep in mind that the sling psychrometer can only be used effectively if the ambient temperature is above 32°F because the freezing point of water is any temperature below that point. You will notice the slope of the psychrometric chart changes to smaller increments as temperature drops in intensity. Wet bulb temperature is plotted from the temperature values given on the saturation or wet bulb scale. To plot a wet bulb temperature, start with the corresponding temperature reading on the wet bulb scale. The wet bulb temperature is plotted on the diagonal line that extends to the right and downward from the wet bulb scale. A wet bulb plot is shown by the heavy line in figure 20. It is not necessary to extend the wet bulb line past its intersection with a previously plotted dry bulb line.

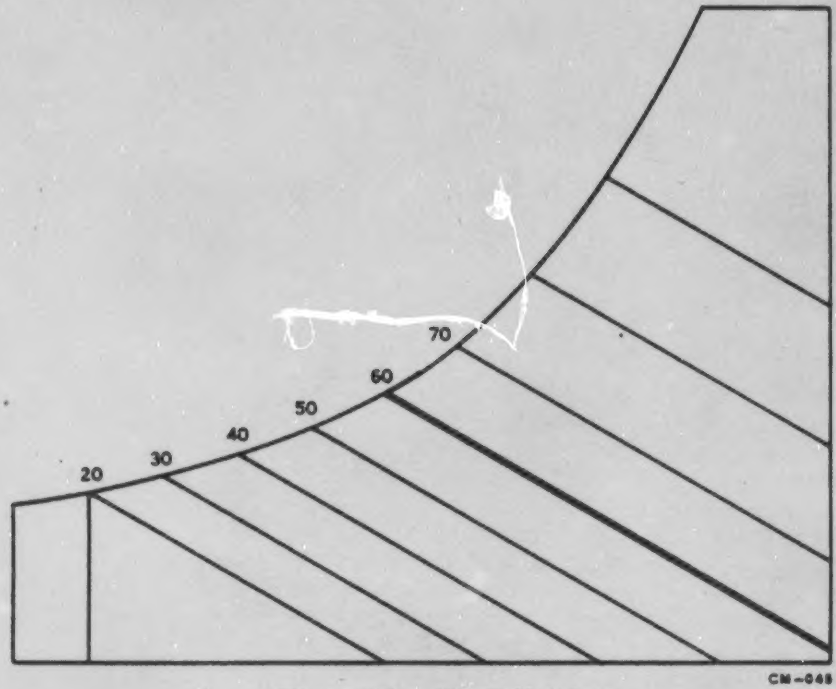


Figure 20. Wet Bulb Line

Relative Humidity (% RH)

Relative humidity is the ratio of the amount of moisture in the air compared to what it could hold at the same temperature.

It is a percentage expression of the grains of moisture contained in the air. Relative humidity is read on or between the curved lines on the psychrometric chart that correspond approximately to the saturation curve at the point of intersection of the wet bulb and dry bulb lines. They are valued from 0-100 percent. The saturation curve is the 100 percent R. H. line. Relative humidity is read at the point of intersection of the dry bulb and wet bulb lines (figure 21).

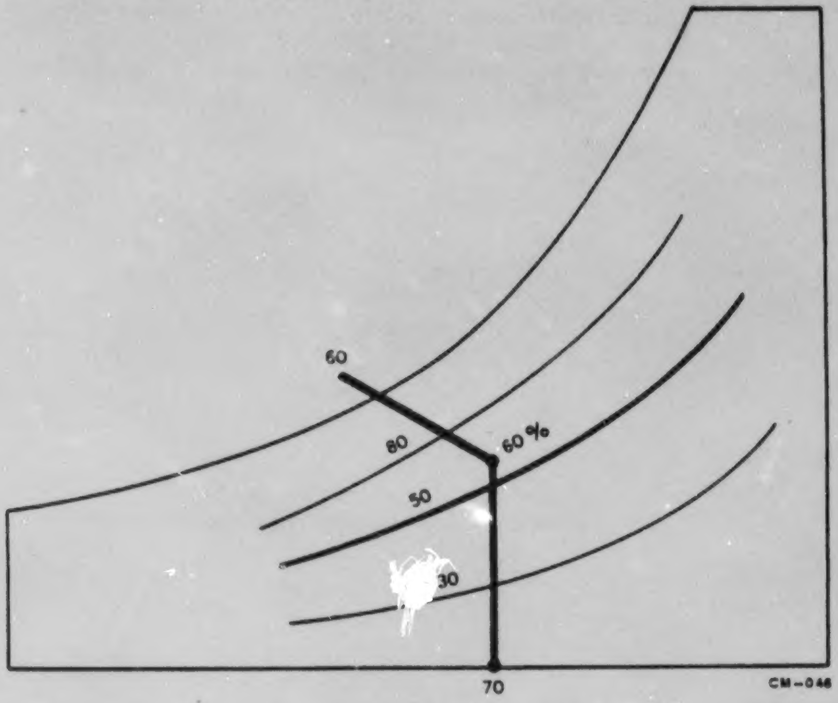


Figure 21. % Relative Humidity

Dewpoint (DP)

Dewpoint or saturation temperature, both terms mean the same. Dewpoint or saturation temperature is the temperature that will allow moisture to condense on a surface. This is exemplified by the droplets of moisture, called dew found on the grass in the warmer months, or by the frozen dew (frost) in the winter months. Windows or containers that sweat have an extreme of temperature on each side of the surface and are examples of dewpoint temperature being reached. Dewpoint is plotted on the horizontal line of the psychrometric chart that extends from the point of % RH to the saturation curve and the value is read at the point of intersection with the curve (see figure 22).

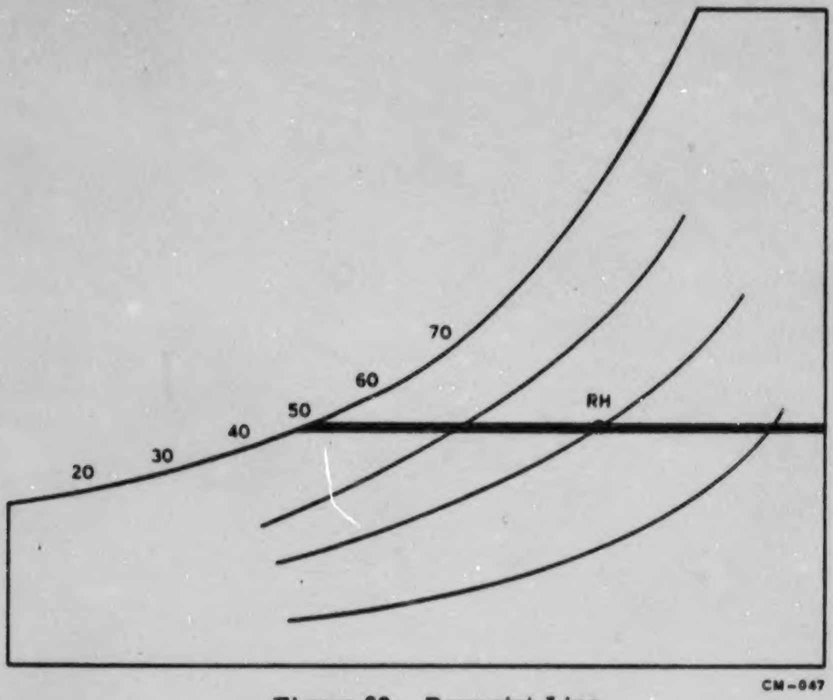


Figure 22. Dewpoint Line

Heat Content or Enthalpy

Both terms mean the same. Heat content is the measure of the Btu contained in one pound of dry air. Heat content is plotted by extending the wet bulb line through the saturation curve to the heat content or enthalpy scale located located to the left of the saturation scale. Read the Btu value at the point the extended wet bulb line intersects the heat content scale as shown in figure 23.

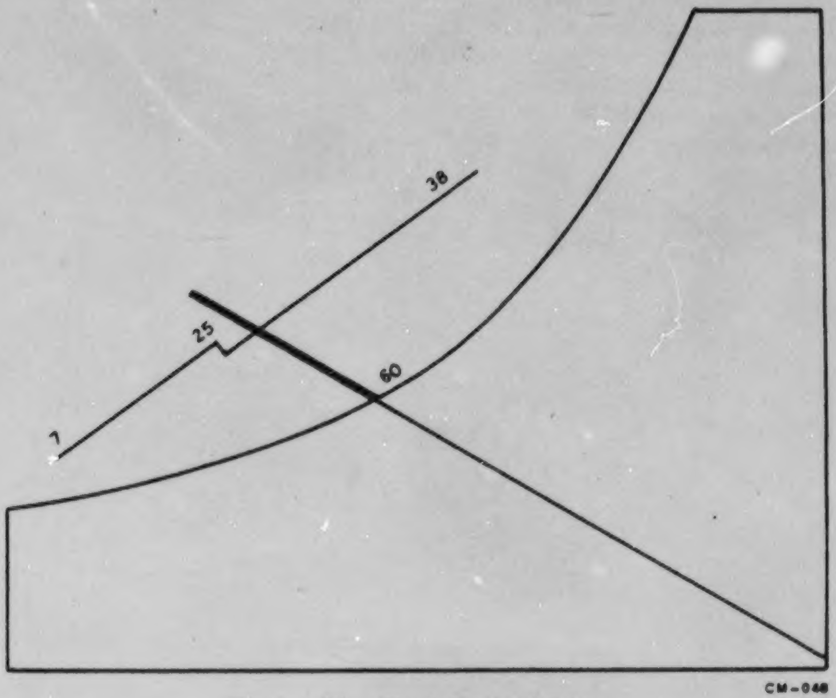


Figure 23. Heat Content Line

Grains of Moisture (GM)

Grains of moisture or specific humidity--both terms mean the same. Grains of moisture or specific humidity is the unit of measurement expressing the actual amount of moisture contained in one pound of dry air. Relative humidity can be determined from this measurement, but you use %RH to determine grains of moisture. A grain of moisture is about the same as a drop of water. A pound of water (about 1 pint) contains 7,000 grains. To plot grains of moisture contained per pound, draw a horizontal line from the point of %RH to the grains of moisture scale and read the intersecting value on the chart (see figure 24).

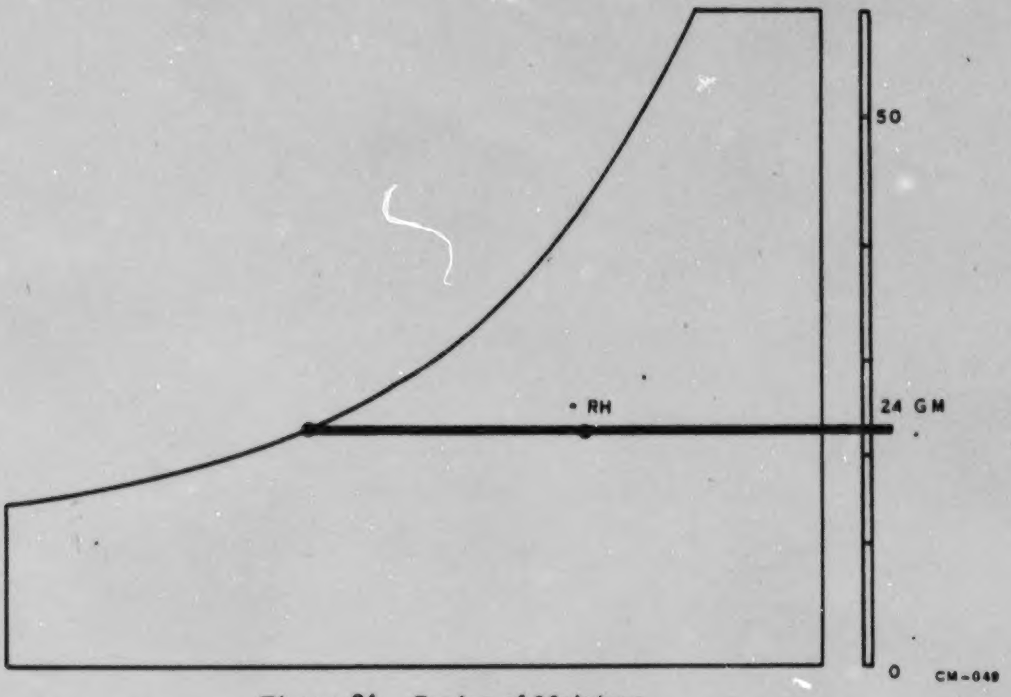


Figure 24. Grains of Moisture

Specific Volume (SV)

Specific volume is the number of cubic feet of air required to weigh one pound. The specific volume lines appear as diagonal-parallel lines extending from the saturation curve to the dry bulb scale. There are five of these lines and they have a corresponding value of 12.5 cu ft thru 14.5 cu ft reading from left to right (see figure 26). To plot specific volume, draw a line parallel to the established specific volume lines from the point of % RH to the dry bulb scale.

To read specific volume plots, start with the specific volume line to the left of the new plot. For every degree Fahrenheit graduation on the dry bulb scale, add .025 until you reach the new line that you drew. Each group of four graduations will increase the specific volume .1 cu ft. Five groups of four graduations will raise the volume .5 or to the next established line of the chart (see figure 27).

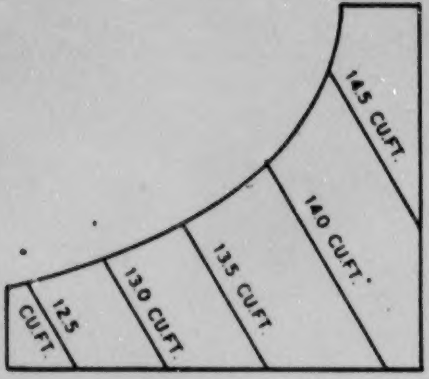


Figure 26. Specific Volume Lines

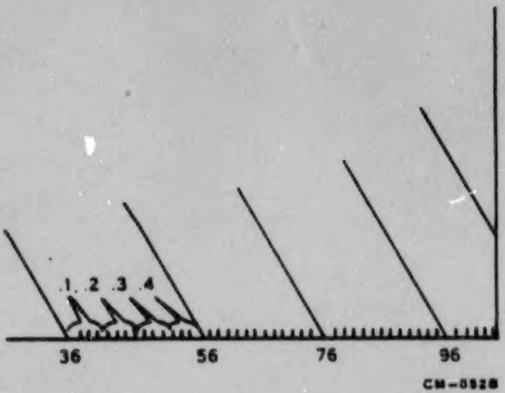


Figure 27. Specific Volume Scale

Standard Air

Standard air is one pound of dry air at 70°F, at atmospheric pressure (14.7 psia) which occupies 13.34 cu ft and has a specific density of .075 at sea level (see figure 28).

This standard is used as a guideline for the manufacturers of coils, fans, and other air-conditioning equipment. Practically all substances will contract or expand with temperature variations. Figure 28 is a graphic illustration of the conditions involved when speaking of standard air.

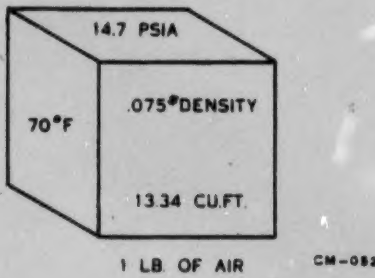


Figure 28. Standard Air

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Pounds of Moisture

Pounds of moisture per pound of dry air is the weight of the grains of moisture contained in one pound of dry air. It is determined by drawing a horizontal line from the grains of moisture plot to the pounds of moisture scale and reading the corresponding value at the point of intersection with the scale (see figure 25).

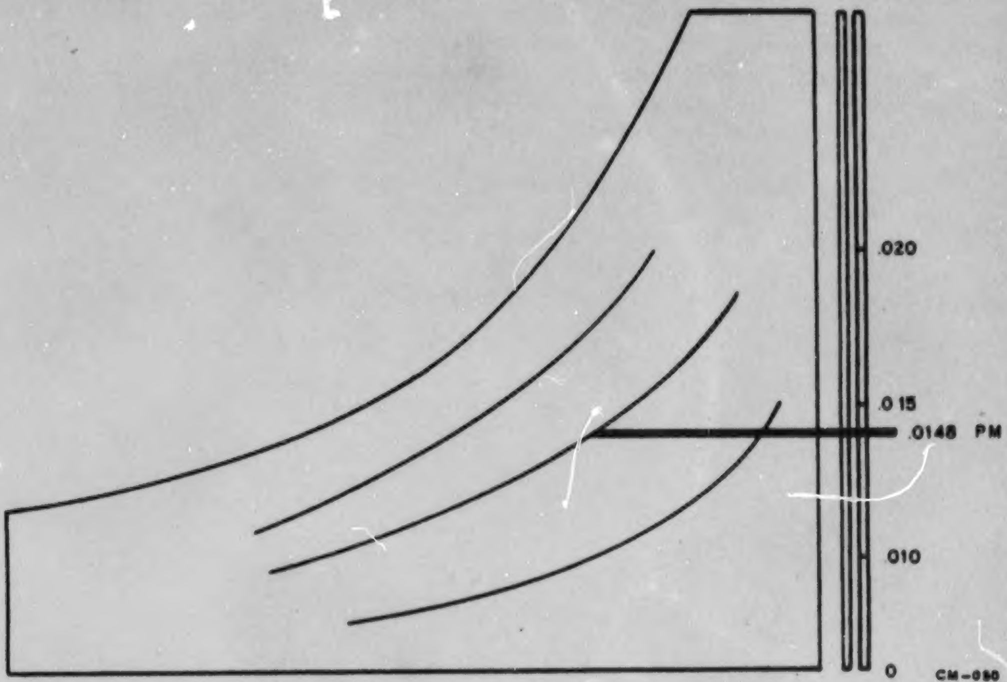

Figure 25. Pounds of Moisture Line

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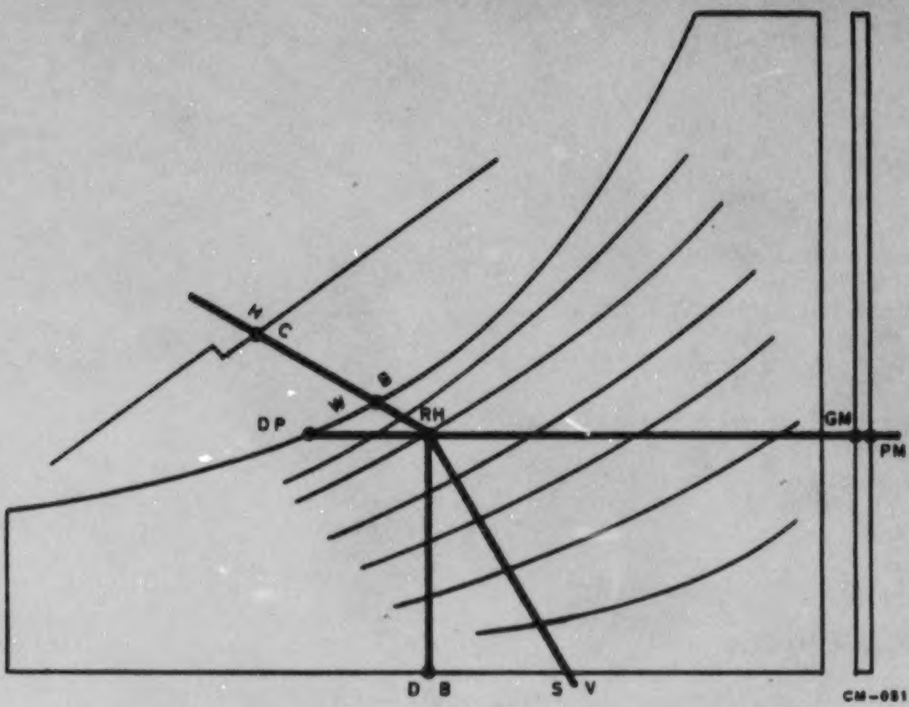

Figure 29. Psychrometric Plot

At this point we have defined the lines and the scales that we will use on the chart. Figure 29 shows a composite of the lines discussed and the relationship of the various lines and scales to each other. This figure shows only a single plot, but psychrometric analysis will involve two to four plots in order to compare all of the temperatures and properties.

To have a good comparative analysis of the air, we must be able to identify the various names given to the air as it goes through the system. Air at outside conditions is called Outside Air (OA). It is introduced into the system through the ducts and various plenums, taking on other names during its travels.

Supply Air (SA) (air leaving coil) is the air that is cooled to the final desired condition and supplied to the controlled space. As it is recirculated into the return duct, it becomes Return Air (RA) (air entering the coil). If the air is to be exhausted to offset the OA brought in, then the air exhausted is labeled as Exhaust Air (EA). If any of the air types are mixed in a mixing plenum, then the name given to the air following this process is Mixed Air (MA). All of these situations can be plotted. Mixed air will be covered later.

Psychrometric Problems

In solving psychrometric problems, we will plot the conditions of the air passing through the system. To graphically illustrate the conditions of the air at given points, we must identify a few more terms that will apply in thi[illegible]nalysis. Some of the terms include the following:

- Grains of Moisture Removed
- Pounds of Moisture Removed
- Total Btu Removed
- Sensible Btu Removed
- Latent Heat Btu Removed
- Coil Slope
- Room Slope
- Apparatus Dewpoint
- Mixed Air Plots

NOTE: In psychrometrics, all values on the chart are per pound of dry air.

GRAINS OF MOISTURE REMOVED. This quantity is found by subtracting the GM of the smaller plot considered from the GM of the larger plot being considered.

For example if the RA plot contained 98 GM and the SA plot contained 77 GM, subtract 77 from 98 and the difference would be 21 GM removed.

POUNDS OF MOISTURE REMOVED. This amount would be determined by the same procedure. If the OA plot contained .014 lb and the CA plot contained .0076 lb, subtract .0076 from .014 and the difference would be .0064 pounds of moisture that were removed.

HEAT CONTENT REMOVED. This can be found by subtracting the HC of the smaller plot from the HC of the larger plot and the difference would be the Btu heat content difference. Earlier in this course you learned that total heat is sensible heat plus latent heat. Therefore, when necessary, the total heat removed can be separated into specific amounts of sensible heat and latent heat.

Sensible heat is heat that changes the temperature of a substance but not its state. Latent heat is heat that changes the state of a substance but not its temperature. When applied to water, sensible heat changes the temperature of the water but it remains water. Latent heat changes water at 212°F to steam at 212°F, thereby changing its state from a liquid to a vapor but with no change of temperature. Sensible heat is measurable with a thermometer; latent heat is not. In air-conditioning work, latent heat is involved only by the addition or removal of moisture in the air. The psychrometric chart is the only tool you have to calculate latent heat.

The total heat removed by an air conditioning unit is simple to calculate on a psychrometric chart. You begin by determining both the dry bulb and wet bulb temperature of the supply air and the return air. Plot both dry bulb temperatures on the chart, as shown in figure 30. Then, plot the wet bulb temperatures and extend their lines through the heat content scale. The total heat removed is the difference between the Btu readings taken at the intersection points of the WB lines with the heat content scale. For example, as shown in figure 30, 34 minus 15 equals 19 Btu of heat removed.

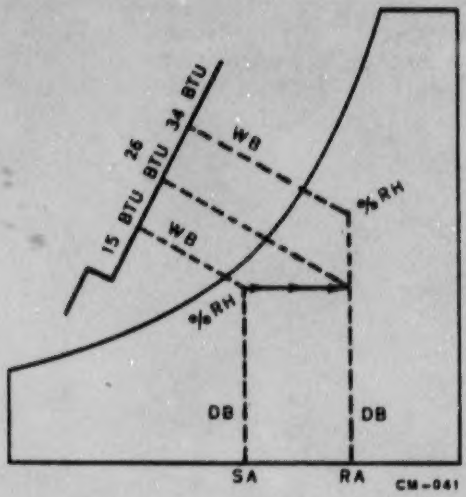

Figure 30. Heat Removal Plots

When necessary, you can determine how much of the heat removed is sensible heat and how much is latent heat. To determine sensible heat, draw a horizontal line from the % RH point for SA until it intersects with the RA line as shown in figure 16. From this point of intersection, draw a line parallel to the WB lines to the heat content scale. The difference in the Btu readings at this point and the SA wet bulb line is sensible heat. As shown in figure 30, 26 minus 15 equals 11 Btu of sensible heat. Latent heat is the total heat minus sensible heat. Following through on figure 30, this is 19 minus 11, giving a latent heat (figure 30) content of 8 Btu.

COIL SLOPE. This is the amount of Btu removed from the air entering and leaving a coil. To graphically illustrate coil slope, you must join the % RH points of the TE and the TL with a straight line, and read the answer on the HC scale by subtracting the HC of TL from the HC of TE (see figure 31).

ROOM SLOPE. This is the amount of Btu that are picked up in a room from the time air enters as supply air and leaves as return air. Plotting procedures are the same as for coil slope; join the % RH of TE and the TL with a straight line and read the answer on the HC scale by subtracting the HC of SA from the HC of RA and recording the difference (see figure 31).

APPARATUS DEWPOINT. This is the temperature of the cooling coil. The term apparatus dewpoint refers to the cooling coil of an air-conditioning system. To plot apparatus dewpoint, join the % RH of TE of the coil and the TL of the coil and extend the straight line to the saturation curve and read the temperature at the point of intersection. Most manufacturers design their units with coils to be maintained at 40°F, to prevent freezeup of the coil.

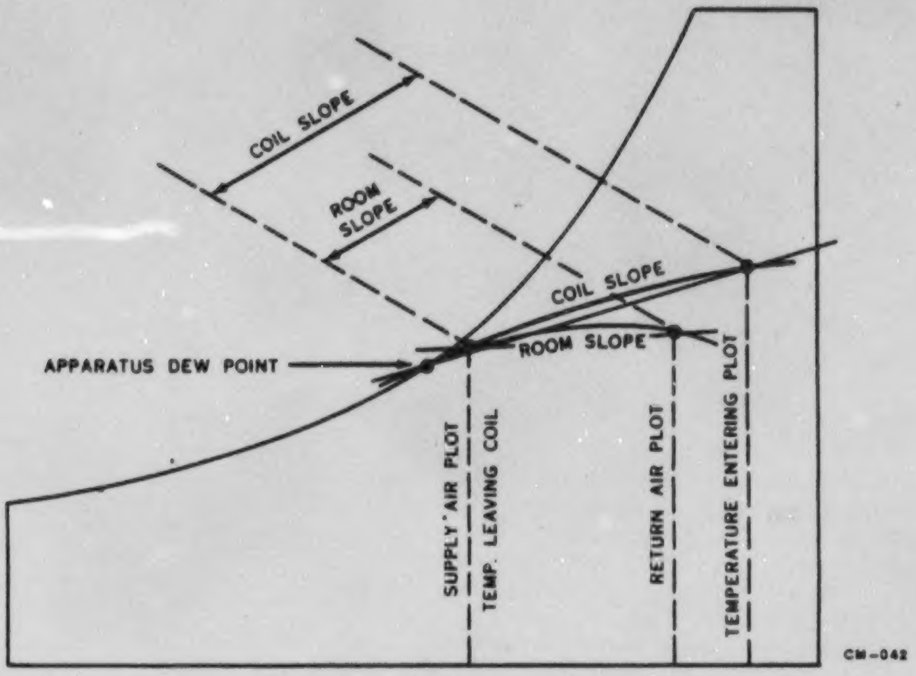
COIL SLOPE
ROOM SLOPE
COIL SLOPE
ROOM SLOPE
APPARATUS DEW POINT
SUPPLY AIR PLOT
TEMP. LEAVING COIL
RETURN AIR PLOT
TEMPERATURE ENTERING PLOT
CM-042

Figure 31. Coil Slope, Room Slope, and Apparatus Dewpoint

SUMMARY

The analysis of air is a valuable tool for the specialist. Psychrometrics give him an understanding of what the mechanical cooling process must overcome to properly perform. In order to correctly determine the properties of air, the refrigeration specialist must be able to use the psychrometric chart.

QUESTIONS

1. What are the five properties of air?
2. What is the difference between relative and specific humidity?
3. What is standard air?
4. Why should distilled water be used with a sling psychrometer?
5. What are the six main scales on the psychrometric chart?
6. What does enthalpy per pound of dry air mean?
7. How is specific density determined?
8. On what line of the psychrometric chart is sensible heat removed?

REFERENCES:

1. AFM 85-18, Maintenance and Operation of Refrigeration, Air-Conditioning and Evaporative Cooling and Mechanical Ventilating Systems.
2. Textbook, Trane Air Conditioning Manual
3. Textbook, Air Conditioning, Delmar
4. Textbook, Modern Refrigeration and Air Conditioning, Althouse, Turnquist and Bracciano

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WORKBOOKS
3ABR54530-VIII-1-P1 thru 3-P2

Technical Training

Refrigeration and Air Conditioning Specialist

TYPICAL AIR-CONDITIONING EQUIPMENT AND PSYCHROMETRICS

October 1975

USAF SCHOOL OF APPLIED AEROSPACE SCIENCES
Department of Civil Engineering Training
Sheppard Air Foce Base, Texas

11-8

Designed For ATC Course Use

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This supersedes Study Guides 3ABR54530-VIII-1 thru 3, and Workbooks 3ABR54530-VIII-1-P1 thru 3-P2, October 1973
(Copies of the superseded publications may be used until the supply is exhausted.)

Dept of Civil Engineering Training
Sheppard AFB, Texas

WB 3ABR54530-VIII-1-P1
October 1975

SELECT FAN, FILTER, AND INSULATION

PART 1--Fans

OBJECTIVE: Using Study Guide 3ABR54530-VIII-1 and air conditioning trainers, identify major components, their types, purpose, and principle of operation with no more than two errors.

PROCEDURES FOR PART 1, 2, and 3

Research and answer the following questions using SG 3ABR54530-VIII-1 and instructions provided by your instructor.

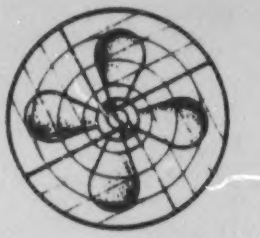
1. What type fan is best for overcoming the resistance of a duct system?

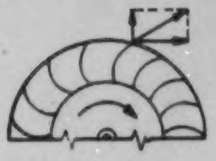
2. What applications are the axial flow fans best suited?

3. Why does a radial flow fan consume more power when not discharging into a duct system?

4. What is the purpose of the vane in the vane-axial type fans?

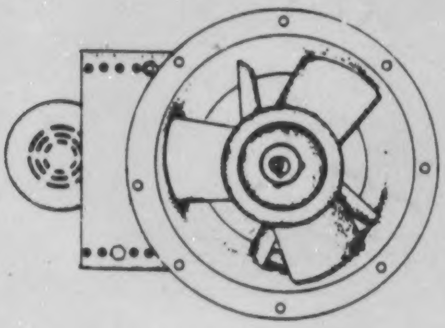
5. Identify the following types of fans.

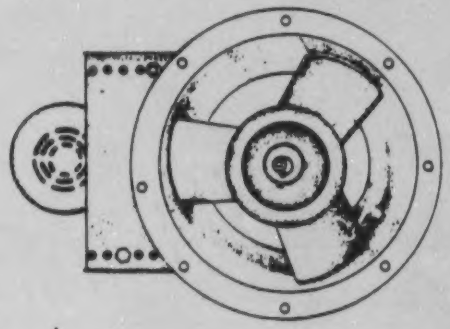




a. ______________________________

b. ______________________________





c. ______________________________

d. ______________________________

Figure 32. Typical Fans

PART 2--Filters

1. Why are filters sometimes coated with a viscous coating?____________________

____

2. What is the major difference between permanent and throwaway filters as far as construction?____

____

3. What types of filters would be most applicable for a conditioned space that must be dustfree?____

____

4. Why are filters located upstream to the fan and cooling coils?________________

____

5. Filters are used to control the air content in regard to ____________________, ____________________, ____________________ and ____________________.

6. Identify the following filter media as permanent or throwaway.

a. Fiberglass	____________________
b. Glass Wool	____________________
c. Aluminum	____________________
d. Gauze	____________________
e. Sponge Rubber	____________________

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PART 3--Insulation

1. The two main purposes of insulation are ____________________ and ____________________ ____________________.

2. Describe the characteristics of a good insulation.

   a. ____________________

   b. ____________________

   c. ____________________

   d. ____________________

   e. ____________________

   f. ____________________

   g. ____________________

   h. ____________________

3. List the types of insulation commonly used in air conditioning.

   a. ____________________

   b. ____________________

   c. ____________________

   d. ____________________

   e. ____________________

   f. ____________________

4. List the type of insulation best suited for the following applications.

   a. Hot Water or Steam ____________________

   b. Supply Air Ducts ____________________

   c. Attics ____________________

   d. Walls ____________________

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PART 4--Airflow through the Duct System

PROCEDURES

Using a duct schematic, label the parts and indicate direction of airflow.

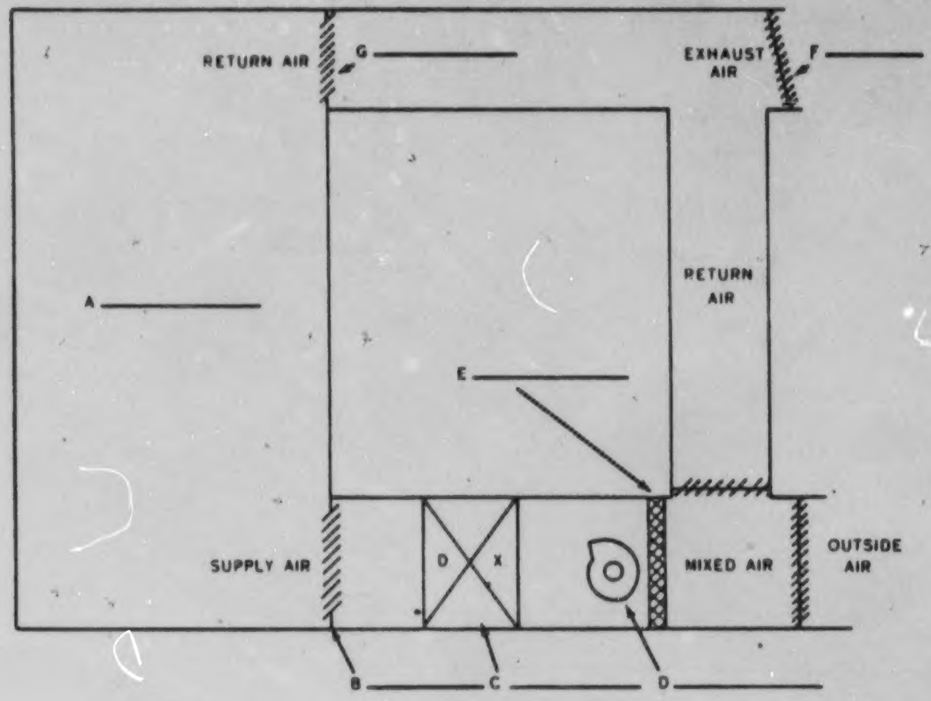
RETURN AIR
G
EXHAUST AIR
F
A
RETURN AIR
E
SUPPLY AIR
D X
MIXED AIR
OUTSIDE AIR
B
C
D

Figure 33. Duct System (Top View)

1. Label the items indicated by letters in the schematic.
2. Use arrows to show the airflow through the duct system.
3. What do the initials DX stand for?________________________________.
4. Could a chill water coil be used in place of the DX coil?____________________.
5. Could the fan be located downstream from the coil?______________________.

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FAMILIARIZATION OF WINDOW AIR CONDITIONERS

PART 1

OBJECTIVE: Provided with a window air conditioner trainer, required tools and workbook, correctly operate and service the unit.

PROCEDURES for Part 1

Using window unit trainer, identify major components, fill in blanks from information provided on data plate and trace flow of refrigerant and airflow on system.

PROCEDURES for Part 2

Following procedures in workbook, perform preoperational check, operate, troubleshoot, and answer questions as required.

FAMILIARIZATION

1. Locate the following units:

   a. Fan motor

   b. Evaporator fan

   c. Condenser fan

   d. Evaporator

   e. Condenser

   f. Air filter

   g. Thermostat

   h. Selector switch

   i. Metering device

   j. Compressor

2. Fill in the blanks:

   a. Compressor: phase________________, voltage______________,
   running amps______________and compressor capacity____________.

   b. Evaporator fan motor hp________, voltage__________________,
   running amps____________.

   c. Manufacturer of unit__________________.

   d. Charge______________lb of refrigerant____________________.

   e. Test pressure_______psi low side, ____________psi high side.

3. Start at the compressor and trace the flow of refrigerant through the system.

4. Start at the filter and trace the flow of air through the system.

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PART 2

TO OPERATE AND TROUBLESHOOT A WINDOW AIR CONDITIONER

1. Perform preoperational checks
   - a. Disconnect the power cord.
   - b. Remove cover.
   - c. Check fans for freedom of movement.
   - d. Check security of mounting of components.
   - e. Inspect filter.
2. Operation.
   - a. Be sure that the thermostat is in the OFF position.
   - b. Plug in the unit and turn the blower to LOW FAN.
   - c. Allow the fan to operate for 30 seconds.
   - d. Turn selector switch to LOW COOL.

     NOTE: Compressor may not operate due to low ambient temperature.
   - e. Adjust thermostat to bring compressor on.
   - f. Allow compressor to operate for approximately three minutes.
   - g. Determine supply air temperature________________________degrees.
   - h. Turn selector switch to HIGH COOL and operate for approximately three minutes.
   - i. Determine supply air temperature______________________degrees.
   - j. Turn selector switch to OFF.

     NOTE: Wait at least two minutes before attempting to restart.

     WHY?____
   - k. Unplug unit.

(3) Fan motor will not operate.

(a) Probable causes

(b) Remedy

b. Use diagnostic chart to check window unit for common malfunctions.

c. Install manifold gage assembly and check system for abnormal low and high side pressures and indications of restricted refrigerant lines.

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3. Trouble Diagnosis

a. Without referring to SG 3ABR54530-VIII-1, list the probable causes and remedies for the following troubles.

(1) Insufficient cooling

(a) Probable causes

____

____

____

(b) Remedy

____

____

____

(2) Compressor will not start.

(a) Probable causes

____

____

____

(b) Remedy

____

____

____

PART 3

PROCEDURE

Using a window air conditioner, inspect the unit, check for correct installation and change the system following outline procedures.

1. Inspection

   NOTE: All power OFF.

   a. Unplug power cord.

   b. Check fan bearings for lubrication.

   c. Clean or replace filter as necessary.

   d. Check unit for cleanliness, clean if necessary.

   e. Check condition of evaporator and condenser fins, straighten if necessary.

2. Maintenance and Installation.

   a. Servicing and replacing fans:

      (1) Check direction of rotation.

      (2) Check and clean blade to assure design airflow.

      (3) Replace damaged fan with one that moves same air volume.

         (a) How does incorrect air volume effect the system performance?

         ____

         ____

         ____

         (b) Will a higher fan speed overload the motor? ____________

         ____

         (c) What should be considered when replacing the fan motor? ______

         ____

         ____

         ____

         ____

b. **Window unit installation:**

(1) The back of the unit should be 1/2" - 1/4" lower than the front to allow

____

____.

(2) If the power cord that is supplied with the unit is not long enough, what precaution should be taken? ____________________________________

____.

(3) What type power receptacle would be used with the following voltage and amperage ratings?

(a) All 115v units ____.

(b) 208-230v, 0-12 amps ____________________________________.

(c) 209-230v, 12.1-16 amps __________________________________.

NOTE: In accordance with National Electrical Code, the maximum allowable current on a 15-amp circuit is 12 amps. Normal ratings for 115v air conditioners will not exceed 12 amps.

(4) In reference to the above note, why are window air conditioners connected to a separately fused circuit? ____________________________________

____

c. Charging Procedures:

NOTE: All power OFF.

(1) Data Plate Information. Type of refrigerant ________________________. voltage ____________, FLA ______________, amount of charge ____________________.

(2) Evacuate system, inches of vacuum ________________.

(3) Add refrigerant to minimum pressure of 60 psi.

(4) Leak check system. Leaks: YES ____________ NO ____________.

NOTE: Turn power ON.

(5) Charge refrigerant gas into the low side of the system.

(6) Start unit compressor and monitor the pressures.

(7) Restrict the condenser airflow so as to create a discharge pressure equivalent to outdoor conditions. (This will simulate actual operating discharge pressures and cause correct refrigerant flow through capillary tube.)

(8) Continue to charge until a 40-degree evaporator is reached. (CAUTION: If entering air is below 80 degrees, a forty-degree evaporator may not be reached without overcharging.)

(9) Pressures________psi high side______________psi low side.

NOTE: Pressure on high side should still be equivalent to outdoor conditions plus thirty degrees heat of compression.

(10) Check running amperage__________FLA. (This may be low due to low entering air temperature.)

(11) What is the temperature difference?__________________________________.
(Normal temperature difference is twenty degrees.)

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Instructor

FAMILIARIZATION OF RESIDENTIAL HEATING AND COOLING SYSTEMS

PART 1

OBJECTIVE: Using workbook and residential air conditioner, identify major components, and their functions errorfree.

PROCEDURES

Using the Residential Air Conditioner trainer, identify all numbered components and state their functions.

Locate the numbered components, identify, and state their function.

NUMBER	COMPONENT	FUNCTION
1.	____________	____________________ ____________________
2.	____________	____________________ ____________________
3.	____________	____________________ ____________________
4.	____________	____________________ ____________________
5.	____________	____________________ ____________________
6.	____________	____________________ ____________________
7.	____________	____________________ ____________________
8.	____________	____________________ ____________________

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NUMBER	COMPONENT	FUNCTION
9.		
10.		
11.		
12.		
13.		
14.		
15.		
16.		
17.		
18.		
19.		
20.		

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PART 2

PROCEDURES

Operate the residential air conditioner in both heating and cooling cycles.

1. Perform preoperational check.

    a. Cooling cycle.

        (1) Check power source.

        NOTE: Crankcase heater must be in operation at least 12 hours prior to operation.

            (a) What is the function of the crankcase heater? ____________________

            ____

        (2) Heat-Cool switch OFF.

        (3) Turn gas supply valve OFF. NOTE: The gas supply is left ON when the heating-cooling system features automatic changeover.

        (4) Check return air grille and filter for obstructions and cleanliness.

        (5) Check condenser fins for obstructions.

    b. Heating cycle.

        (1) Heat-Cool switch OFF.

        (2) Turn main gas supply ON.

        (3) Check for gas leaks.

        (4) Check flue for obstructions.

        (5) Light the pilot.

        (6) Check return air grille and filter for obstruction and cleanliness.

2. Perform starting procedures.

    a. Select heat or cool.

    b. Select fan automatic or manual position.

    c. Set thermostat for desired temperature.

    d. Check operation of system.

3. Accomplish operational checks.
   a. Observe burner flame and adjust accordingly if in heating.
   b. Observe refrigerant sight glass if in cooling.
   c. Check unit for unusual noise or excessive vibration.
   d. Check supply air for proper flow and air distribution.
   e. Check wet bulb and dry bulb temperature of supply air.
4. Accomplish shutdown procedures.
   a. Turn heat-cool selector switch to OFF.
   b. Turn main gas valve OFF.

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HEATING AND COOLING WIRING DIAGRAMS

OBJECTIVE: Using workbook and residential air conditioner trainer, trace electrical circuits errorfree.

PROCEDURES

1. Using diagram below, identify the components controlled by the thermostat according to color coded wiring.

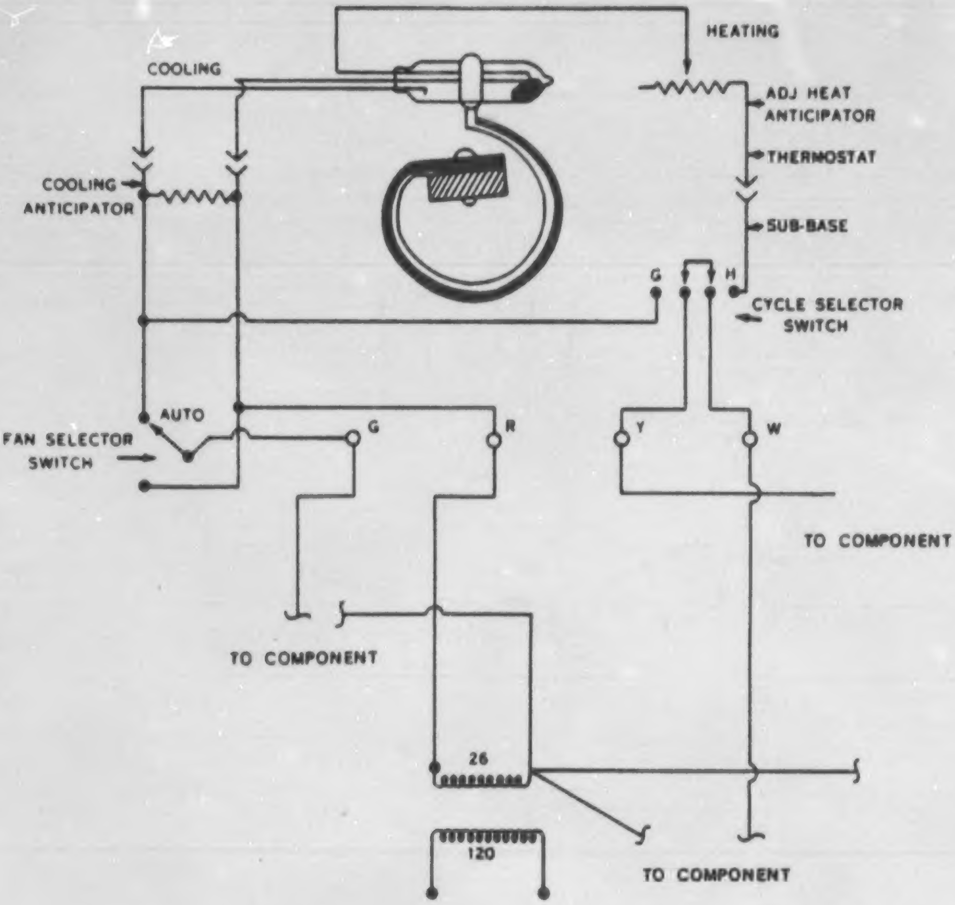
HEATING
COOLING
ADJ HEAT ANTICIPATOR
THERMOSTAT
COOLING ANTICIPATOR
SUB-BASE
G
H
CYCLE SELECTOR SWITCH
AUTO
FAN SELECTOR SWITCH
G
R
Y
W
TO COMPONENT
TO COMPONENT
26
120
TO COMPONENT

Figure 34. Low Voltage Thermostat

a. Terminal G. ______________________________

b. Terminal Y. ______________________________

c. Terminal W. ______________________________

2. Complete the following wiring diagrams.

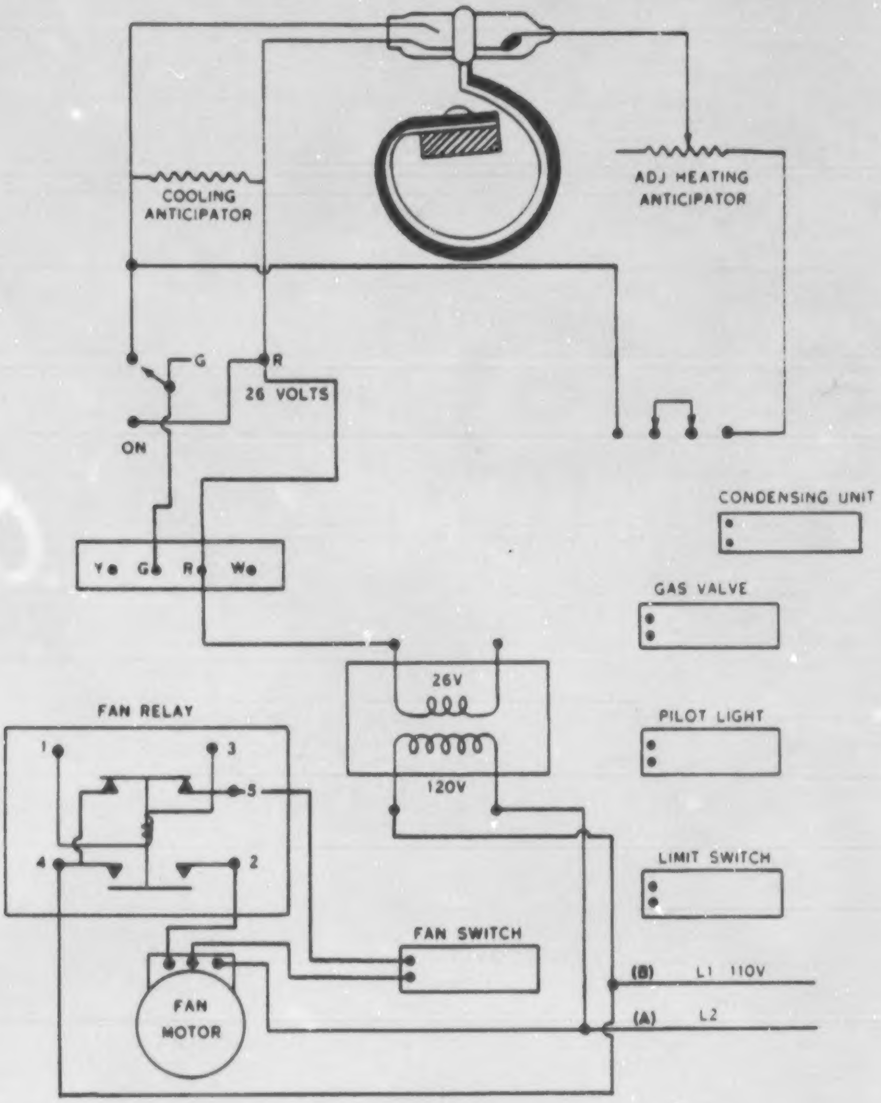
COOLING
ANTICIPATOR
ADJ HEATING
ANTICIPATOR
G
R
26 VOLTS
ON
Y G R W
CONDENSING UNIT
GAS VALVE
26V
120V
PILOT LIGHT
FAN RELAY
1
3
5
4
2
LIMIT SWITCH
FAN SWITCH
FAN
MOTOR
(B) L1 110V
(A) L2

Figure 35. Heating/Cooling Thermostat Wiring

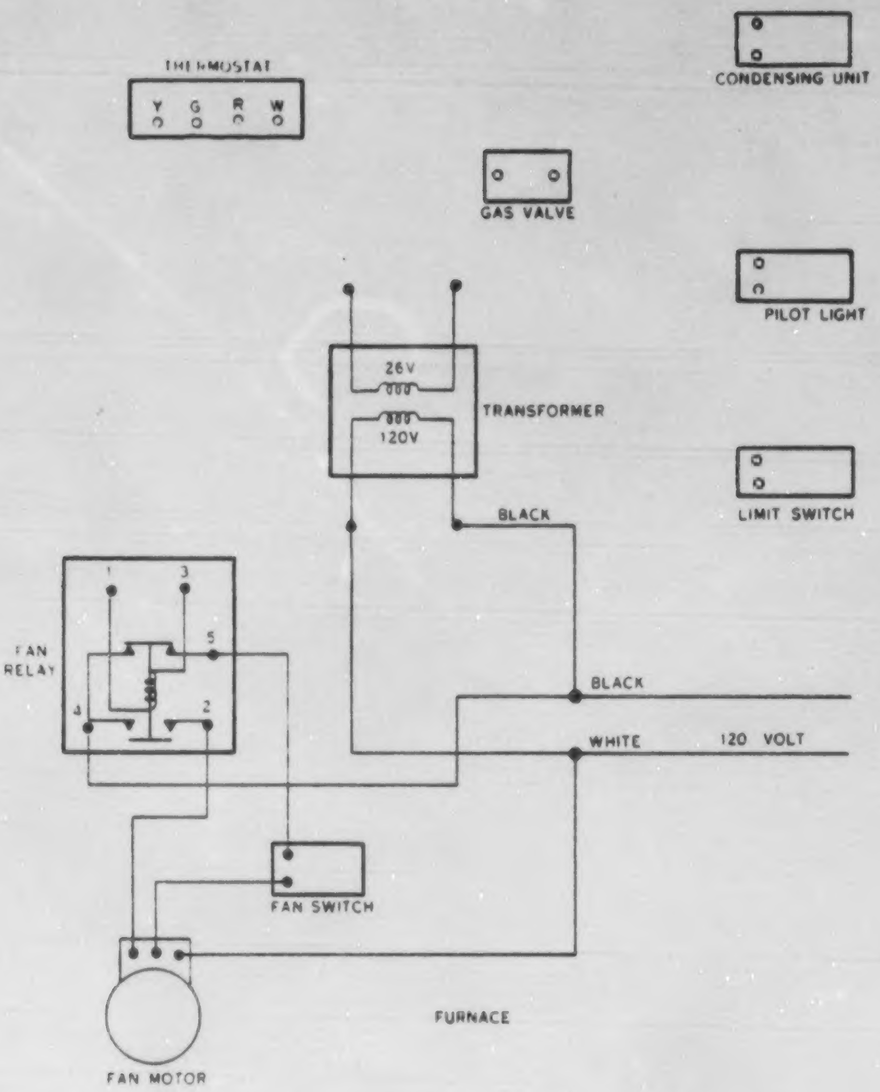
THERMOSTAT
Y
G
R
W
CONDENSING UNIT
GAS VALVE
PILOT LIGHT
26V
TRANSFORMER
120V
BLACK
LIMIT SWITCH
1
3
5
FAN RELAY
4
2
BLACK
WHITE
120 VOLT
FAN SWITCH
FURNACE
FAN MOTOR

Figure 36. Furnace and Condensing Unit Wiring

3. Have instructor check your work.

Checked by______________________________
Instructor

5. From the table below, compute the data using the formulas listed in items 2-4.

	Velocity Pressure	Duct Size	Duct Area	FPM	CFM
1.	.25	12" x 24"			
2.	.36	24" x 36"			
3.	.16	12" x 18"			
4.	.46	36" x 48"			
5.	.09	12" x 12"			

Checked by______________________
Instructor

USING THE ANEMOMETER

1. Measure the height and width of the duct.

   a. Height = ____________________"

   b. Width = ____________________"

   c. Area in sq in = W ___________ X H ______________ = ______________ sq in

   d. Area in sq ft = Area in sq in ________________ ÷ 144 sq in = ________ sq ft

2. Divide the duct area into equal 6" square areas.

   a. Width = ____________________ 6" squares

   b. Height = ____________________ 6" squares

   c. W ________________ X H ________________ = ______________ Total equal 6" squares.

   To find elapsed time you will have to take a reading of 10 seconds at the center of each 6" square.

   d. Elapsed time = No. 6" squares __________ X 10 seconds = __________ seconds

   e. Elapsed time is ______________ seconds.

DETERMINE VELOCITY AND CFM OF AIR

OBJECTIVE: Using workbook, airflow instruments and selected air conditioner, determine CFM to within two percent accuracy.

PROCEDURES

Determine air velocity and volume by using specific airflow instruments.

NOTE: The instructor will show you where the velocity readings should be taken.

USING MANOMETER AND PITOT TUBE

1. Connect the manometer and pitot tube for measuring velocity pressure in the duct.

   What is the velocity pressure (VP)? ______________________ H_2O.

2. Calculate the FPM.

   a. $FPM = 4005 \times \sqrt{VP}$

   b. FPM = 4005 X ________

   c. FPM = ____________

3. Measure the width and height of the duct.

   a. Width = ____________________."

   b. Height = ___________________."

   c. Area in sq in = W__________X H____________ = ______________sq in

   d. Area in sq ft = area in sq in ÷ 144 sq in = ____________________sq ft

4. Figure the CFM.

   a. CFM = FPM X duct area (DA) in sq ft

   b. CFM = _______________X___________________ = _________________.

3. Using the anemometer to measure linear feet.

   a. After completing the measurement of the air, read the linear feet.

      (1) The left dial reads ______________________________

      (2) The right dial reads ______________________________

      (3) The central dial reads ______________________________

      (4) What is the anemometer reading ______________________________

4. Convert the anemometer reading to FPM.

   a. FPM = AR X 60 ÷ ET

   b. FPM = ____________________ X 60 = ______________ ÷ ______________

      ET = ______________

   c. FPM = ____________________

5. Determine the CFM

   a. CFM = FPM X DA

   b. CFM = ____________ X ____________ = ________________

   c. CFM = ____________________

6. From the table below, compute the data using the formulas in steps 1-5.

	Anemometer Reading	Duct Size	Duct Area	Elapsed Time	FPM	CFM
1.	1350	42" x 12"				
2.	880	24" x 12"				
3	1350	48" x 12"				
4.	1200	24" x 12"				
5.	1500	20" x 18"				

Checked by ______________________
Instructor

USING THE VELOMETER

1. Attach testing probes to velometer.

2. Use the velometer to find the FPM.
   You will have to average the readings.

   a. Reading 1 ____________________

   b. Reading 2 ____________________

   c. Reading 3 ____________________

   d. Reading 4 ____________________

   e. Reading 5 ____________________

   f. Reading 6 ____________________

   g. Reading 7 ____________________

   h. Reading 8 ____________________

   Total of readings a through h = ____________________

   Number of readings = ____________________

   Average of readings = Total ÷ Number

   FPM = ____________________

3. Figure the duct area.

   a. Width in inches = ____________________

   b. Height in inches = ____________________

   c. Duct area in sq in = ____________________

   d. Duct area in sq ft = sq in ÷ 144 sq in

   e. DA = ______________ sq in ÷ 144 sq in = ____________________

   f. DA = ____________________

4. Figure the CFM

   a. CFM = FPM x DA

   b. CFM = __________ x __________ = __________

   c. CFM = __________

5. From the table below, compute the data using the formulas in steps 1 through 4.

	Velometer Average Reading	Duct Size	Duct Area	FPM	CFM
1.	500	12" x 12"			
2.	750	12" x 18"			
3.	1000	18" x 18"			
4.	1820	24" x 24"			
5.	2400	36" x 36"			
6.	1280	24" x 30"			

Have the instructor check your work.

Checked by____________________
Instructor

BALANCING AIR-CONDITIONING SYSTEMS

PART 1

OBJECTIVE: Using residential air conditioner trainer and airflow instruments, balance the airflow to meet required specifications in workbook within five percent accuracy.

PROCEDURES

Using heat load formula, determine the volume of air needed to condition a room to a specified temperature.

NOTE: The specified conditions and the hourly heat load for each room are shown on the building blueprint. (Figure 37)

FORMULA: $\text{CFM} = \dfrac{\text{ROOM HEAT LOAD (Btu)}}{1.08 \times \text{TD}}$

NOTE: This formula will determine the CFM needed to handle the HOURLY HEAT LOAD of each room.

DETERMINE THE CFM REQUIREMENT FOR EACH ROOM.

Using the specified conditions and given formula, compute the CFM requirement for each room.

ROOM A. ____________________

ROOM B. ____________________

ROOM C. ____________________

ROOM D. ____________________

ROOM DESIGN TEMPERATURE--75°F (DB)

DESIGN SUPPLY AIR TEMPERATURE--52°F (DB)

DUCT SIZES--ALL 8 inches in diameter.

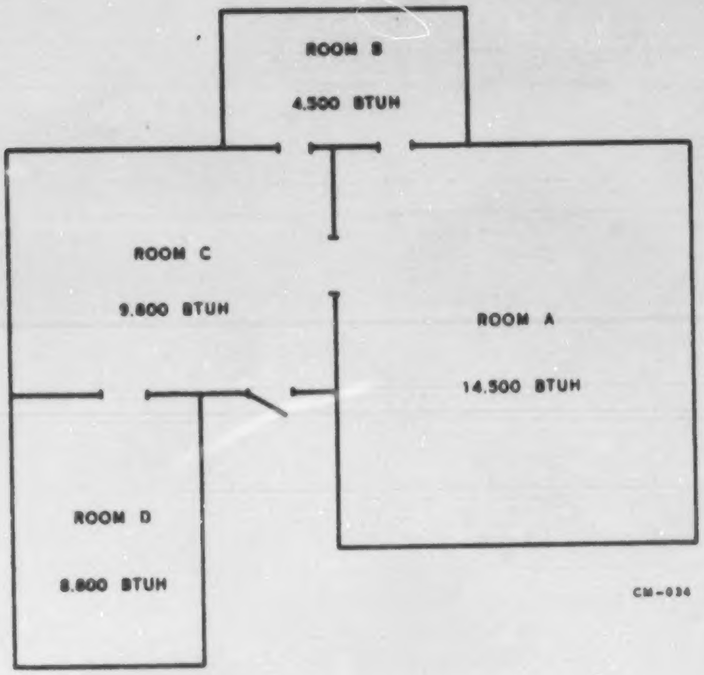
ROOM B
4,500 BTUH
ROOM C
9,800 BTUH
ROOM A
14,500 BTUH
ROOM D
8,800 BTUH
CM-034

Figure 37. Building Diagram

Checked by______________________________
Instructor

PART 2

PROCEDURES

Utilize a method for balancing airflow to meet the requirements as determined in Part 1 of this project.

NOTE: The velometer will be used to measure the airflow.

1. Position dampers and room diffusers to obtain maximum airflow.

2. Check and list the CFM requirements as determined in Part 1 for each room.

   A. ________ B. ________ C. ________ D. ________

3. Determine existing CFM to each of the rooms.

   A. ________ B. ________ C. ________ D. ________

4. Adjust balancing dampers to obtain air volume that is closer to the required CFM.

   NOTE: This step must be repeated several times because each damper adjustment will affect the other air volumes.

5. List the air volumes as you make a round of adjustments.

   A. ________ B. ________ C. ________ D. ________

6. Continue making adjustments until the required CFM is obtained for each room.

7. List your final results.

   A. ________ B. ________ C. ________ D. ________

Checked by____________________
Instructor

USING SLING PSYCHROMETER TO DETERMINE DRY BULB AND WET BULB TEMPERATURES

OBJECTIVE: Using the sling psychrometer, determine the wet bulb and dry bulb temperature of air within two degrees.

PROCEDURES

Using sling psychrometer to determine wet and dry bulb temperatures under varying conditions following instructions below.

1. Using a sling psychrometer, wet the wet bulb thermometer and rotate the psychrometer rapidly until the reading on the wet bulb thermometer reaches the lowest point and stablizes (about 30 seconds).

2. On the following chart, record the reading from both the wet bulb and dry bulb thermometers. Determine the wet bulb depression of the problem.

DRY BULB TEMPERATURE	WET BULB TEMPERATURE	WET BULB DEPRESSION

3. Answer the following questions:

   a. Why does the thermometer with the wet wick indicate a lower temperature than the dry thermometer?

   ____

   ____

   b. When using the sling psychrometer, the difference between the reading of the wet and dry bulb thermometer is called

   ____

   ____

Checked by ______________________
Instructor

USING PSYCHROMETRIC CHART TO DETERMINE THE PROPERTIES OF AIR

OBJECTIVE: Using psychrometric chart and workbook values, determine dewpoint temperatures, relative humidity, specific humidity, and heat content within two percent.

PROCEDURES

Using a psychrometric chart and two known conditions determine other air properties.

PLOTTING AIR PROPERTIES

1. Supply all missing values, using the Psychrometric Chart furnished by the instructor.

	DB	WB	RH	DP	Gr/lb	HC
1	72F				59 gr	
2		61F	45%			
3	85F		60%			
4	68F			24F		
5		71F			63 gr	

2. Under saturated conditions, how much more vapor can 60°F air hold than 30°F air?

____

3. A room air conditioner was started when the temperature was 75°F and the relative humidity (RH) was 70 percent:

   a. How much moisture did the air contain? ____________________

   b. After three hours of operation, the temperature was 70°F and RH 50 percent.

   c. How much moisture had been removed? ____________________

4. A homeowner complains of dryness from his hot air heating system. When checked, the DB temperature was 72°F and the WB temperature was 48°F.

   a. What is the relative humidity (RH)? ______________________________

   b. How much moisture must be added to the system to bring the RH up to

      50 percent? ______________________________

Have the instructor check your work.

Checked by ______________________________
Instructor

ATC-SHEPPARD AFB TEX [illegible]

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STUDY GUIDES
3ABR54530-VIII-5 thru 7

Technical Training

Refrigeration and Air-Conditioning Specialist

HEAT PUMPS, PACKAGE AIR CONDITIONER, AND DIRECT EXPANSION AIR-CONDITIONING SYSTEMS

October 1975

USAF SCHOOL OF APPLIED AEROSPACE SCIENCES
Department of Civil Engineering Training
Sheppard Air Force Base, Texas

8-11

--- Designed For ATC Course Use

DO NOT USE ON THE JOB

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This supersedes SGs 3ABR54530-VIII-5 thru 7, WBs 3ABR54530-VIII-5-P1 thru 7-P11, October 1973. Copies of the superseded publication may be used until supply is exhausted.

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Department of Civil Engineering Training
Sheppard Air Force Base, Texas

SG 3ABR54530-VIII-5
October 1975

HEAT PUMPS

OBJECTIVE

Upon completion of this unit of instruction you will be able to identify the major components of the heat pump trainer as to their type, purpose, and principle of operation and trace the flow of refrigerant through the cooling and heating cycles.

INTRODUCTION

As early as 1500 AD man was designing devices to cool and ventilate his domestic environment. Methods such as water-driven devices, gear-driven devices, and other attempts gradually gave way to our modern concept of air conditioning. Improved technology has expanded this field from domestic to industrial, commercial, military, aviation, transportation, marine, and outer space utilization. In the early 1900's air conditioning was used to control the manufacture of many products (candy, matches, etc). In the 1920's air-conditioning principles were applied to commercial uses such as theaters. This was the birth of our controlled environment application for air conditioning as we know it today.

Air conditioning is defined as "that process used for the control of temperatures, humidity, filtration, and ventilation of air." Air conditioning is playing a more important part in man's environment. His home and automobile, business, and recreational locations are air-conditioned in order that the maximum comfort may be maintained, increasing the efficiency of the activity being performed.

Heat Pumps

A heat pump is an air conditioner that may be used for heating in the winter and cooling in the summer. This is accomplished by reversing the flow of refrigerant so that the inside coil becomes the condenser and the outside coil becomes the evaporator. The reversing is done by a reversing valve (figure 1).

A reversing valve consists of a valve body with four lines and two capillary tube connections, plus a solenoid operated pilot valve. Line one is always the discharge line and line two, the suction line whether the unit is in the cooling or heating cycle. In figure 1B, which shows the heating cycle, the hot, high-pressure gas entering the valve body is being directed out line four to the inside coil. From the inside coil where the heat is dissipated the refrigerant passes by way of the capillary tube to the outside coil where it picks up heat. From the outside coil the refrigerant flows through the line back to the reversing valve and into line two for return to the compressor.

To change from heating to cooling, the solenoid of the pilot valve is deenergized which allows the slide to be shifted by spring pressure. This opens the left end capillary tube to the suction line and closes off the right end capillary. Looking at figure 1A and 1B, you will see there is a bleed hole in each end of the piston. The bleed holes allow gas from the discharge line into both ends of the piston. Due to the right end capillary tube being closed to the suction line, the pressure in the right side increases above the left end and repositions main valve slide to the left. Now, the hot gas from line one is directed to line three going to the outside coil first as in figure 1A.

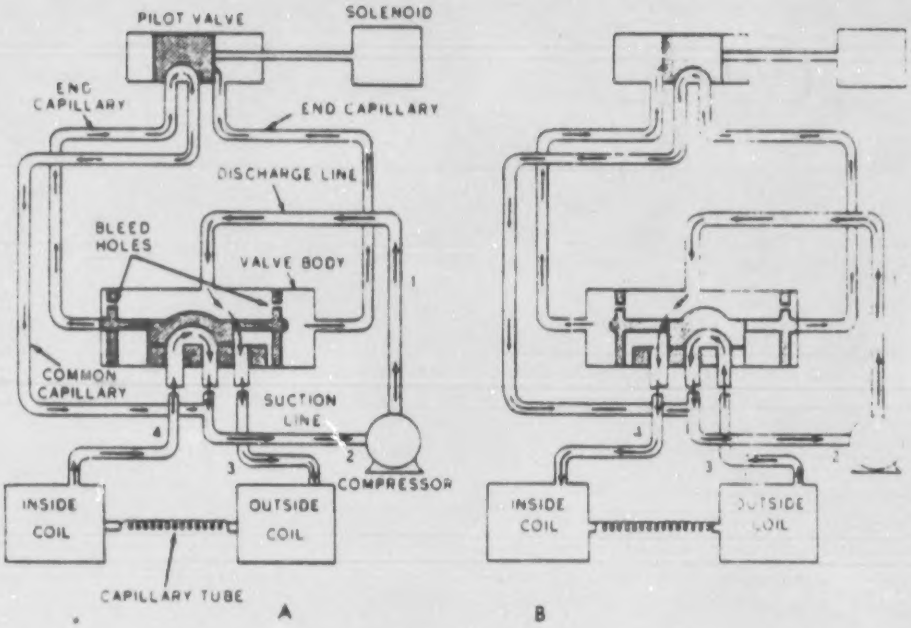

PILOT VALVE
SOLENOID
END CAPILLARY
END CAPILLARY
DISCHARGE LINE
BLEED HOLES
VALVE BODY
1
COMMON CAPILLARY
SUCTION LINE
4
3
2
COMPRESSOR
INSIDE COIL
OUTSIDE COIL
CAPILLARY TUBE
A
4
3
2
INSIDE COIL
OUTSIDE COIL
B

Figure 1. Reversing Valve

Condensers and Evaporator Coils

The coil mounted inside the house is usually a standard finned coil with a blower.

The outside coil comes in a variety of designs. The coil design depends on what substance the coil is to release its heat to or pick up its heat from. Some types of coils classified as to the heat medium are:

1. Air coil
2. Lake water coil
3. Well water coil
4. Ground coil

Air Coil

The easiest to install and the least expensive of the outdoor coils for heat pump use is a coil used to release its heat to the outside air, or to pick up heat from the outside air. This type coil has a number of advantages in climates where the outside temperatures do not vary more than from 20 to 110 F.

The coil itself is a standard heat transfer coil with tubing for primary surface and extended fins bonded to the tubing. A blower is mounted in the housing that protects the coil from the weather. The coils have been mounted on the outside wall of a building on the roof and in separate shelters adjacent to the building.

During the heating cycle there is a tendency for these units to frost and ice in certain weather conditions. To prevent this action, most heat pumps have a special thermostat mounted on the coil. If frost or ice starts to accumulate, this control will shut off the system and start a defrost action (heating coils) or will reverse the cycle long enough to defrost the coil. Some systems use a timer to rid the outdoor coil of frost or ice.

Lake Water Coil

Several installations have been tried where the outside coil is dropped on the bottom of a lake adjacent to the premises. The coil, if installed at the bottom of the lake, has a more constant temperature than otherwise. During the cooling cycle, this coil readily releases its heat to the lake water. During the heating cycle the evaporator coil absorbs heat from the water at the bottom of the lake.

The temperature of maximum density of water is 39°F. This means that the temperature of the water at the bottom of the lake will be 39°F or above. If the water is cooled below 39°F. it will expand and rise to the surface, and a temperature of 32°F will cause it to freeze. This is the reason that ice forms on the surface of a lake. The lake would be frozen solid before the temperature of the water at the bottom could be below 39°F.

From this you can see that a lake, even one covered with ice, may be a reservoir of heat.

Well Water Coil

Well water may provide an efficient heat pickup unit for heating and a good heat dissipator during the cooling cycle.

The cost of the well is a disadvantage, but its cost will probably soon be offset by the lower cost of operation.

A popular method of using well water is to pump the water out of the well, then after heat has been removed from the water or released to it, the water is returned to the well using a tube-within-a-tube or a shell-and-tube heat exchanger.

When well water is 60°F, a condensing temperature of 80°F can be used during cooling cycle. An evaporator temperature of 40°F can be used during heating cycle.

Often flowing wells or springs are used to suppiy water for the heat pump installations.

Ground Coil

A type of outside coil which is receiving considerable attention is a ground coil. It has been found that, regardless of the latitude and the air temperature changes, the temperature in the ground at a depth of 4 to 6 feet changes very little. These temperatures average between 40°F and 60°F.

If a coil is buried in the ground at a depth of 4 to 6 feet and it has sufficient heat transfer surface, the coil can be used as an outdoor coil for both heating and cooling cycles.

Installations have been made using a combination of air coils and either a lake coil, well coil, or ground coil. The air coil is used alone when the outdoor temperature permits efficient operation, but when the outside air becomes too cold or too hot the auxiliary coil may be connected into the system.

Servicing Heat Pumps

Because the heat pump system is a refrigerating unit, the service techniques of troubleshooting and repair are much the same as the service procedures for any refrigeration unit.

Routine maintenance requires that the refrigerant pressures be checked and the voltage and current at the unit be checked. The heat pump should be cleaned. Blow out the coils, clean the duct passages, and oil the fan bearings and fan motor bearings. The unit should be operated on both heating and cooling cycles to check the operation of the reversing valve.

Service calls usually start with a complaint, such as:

1. Unit will not operate on cooling or heat.
2. Units runs too much.
3. System is noisy.

The diagnosis must not only find the cause of the complaint, but must also find the reason for the trouble. For example, a lack of refrigerant indicates a leak. The leak must be found and repaired.

A four-way valve that will not operate must be replaced.

Heat pumps have one main operational problem--freezeup of the outside coil. To prevent freezeup of the outside coil, a defrost thermostat is installed on the unit to switch the coils long enough to change the temperature of the outside coil to prevent freezeup. On misty days where the ambient temperature outside is 32° - 30°F. the unit will spend almost equal time in the heating and defrost cycles.

QUESTIONS

1. List one disadvantage of each type of outside coil used on heat pumps.

2. Name three sources of derived heat for heat pump operation.

3. What is the chief restriction to using heat pumps of the air source type?

4. What component is responsible for actuating the heat pump reversing valve?

5. **What happens as the heat pump reversing valve changes the flow of refrigerant within the system.**

6. **What is the most common problem to heat pumps?**

REFERENCES

Modern Refrigeration and Air Conditioning, Althouse/Turnquist/Bracciano

Air Conditioning (Paul V. Lang)

AFM 85-18, Maintenance and Operation of Refrigeration, Air Conditioning and Evaporative Cooling and Mechanical Ventilating Systems

PACKAGE AIR CONDITIONER

OBJECTIVE

Upon completion of this unit of instructions, you will be able to identify the components and list their functions on the Package Air Conditioner. You will also be able to trace the flow of refrigerant air and water through the system.

INTRODUCTION

The package air-conditioning units differ from the remote unit in that one housing contains all of the components. These units are usually found in offices or in a portion of a building that is separate where it would be impractical to air-condition the whole building because of differing heat loads.

Package air conditioners (see figure 2) are built in sizes from one to 30 tons. This type of equipment is used to cool rather large rooms or areas with or without ductwork. A package unit provides the means for fast and easy conditioning of a large area. If the area is long and narrow or it has partitions or objects that will restrict the airflow, it may be necessary to use ductwork to distribute the air. The main advantage in the use of the package unit is that it can easily be moved from one location to another. For this reason package units are used as part of the mobile equipment due to their ease in moving and ability to become quickly operational.

Service and maintenance for package units are the same as for any other refrigeration system. The components are the same as for any other refrigeration system. They do have some peculiarities of their own.

Refrigerant

The systems in packaged air conditioners will use either R-12, R-22, or R-500 depending on the individual application and desired temperatures being maintained.

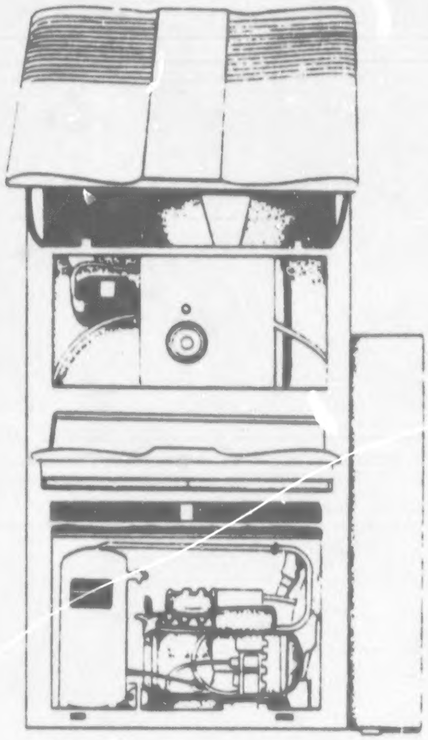


Figure 2. Package Unit

Motors

There are normally three individual motors found on this equipment: the compressor drive motor, the condenser fan motor, and the evaporator blower motor. If the unit has a water-cooled condenser, then the condenser motor is not required.

Power Requirements

These systems are designed to operate on 220-240v ac. single- or three-phase power. The control circuits will range from 24v ac to line voltage.

Blowers

The evaporator blower is usually of the squirrel-cage type. In some cases the unit will have two individual blowers to facilitate the air movement. A double blower could be attached to separate motors or be driven by a single motor having a double shaft.

Fans

The condenser fan can be of the squirrel-cage or the propeller type. The fan-blade style will be governed by the amount of heat to be dissipated from the condenser coil, local wind velocities, etc. The condenser fans are usually wired into the circuit through a pressure sensing switch used as a controller. As the pressure increases or decreases, the fan(s) will become active or inactive. This is known as cycling the fan and is one of the methods of capacity control.

Condensers

The most common is the air-cooled condenser. Refrigerant cooling is obtained by adequate condenser surface and maximum air circulation over the coil and fin surface. The shell and tube water cooled condenser consists of a gas type sealed shell containing a copper coil or tubes. The hot refrigerant gas is admitted into the condenser shell and flows down over the condenser tubes in which cooling water is circulated. The gas condenses on the surface of the tubes and runs to the bottom of the condenser shell. These condensers are used frequently where the cooling load is heavy and the ambient temperature may rise above 90°F. These units require plumbing connections to both fresh water and a drain for return water and condensate from evaporator coil or a water cooling tower whichever is used. The flow of water through the condenser is controlled by a water pressure regulating valve which has a small tube connected to the compressor sensing the head pressure. As the head pressure varies the flow of water varies to maintain a constant head pressure.

Compressor

Any of the styles of compressors can be found in package units: hermetic, semihermetic, and open.

It is not uncommon to see two compressors in a package unit. Each compressor is independent of the other and feeds a portion of the split evaporator. This type of system is convenient not only to the maintenance man, but it will continue to operate at 50 percent capacity if one of the compressors develops trouble. The maintenance man can isolate the defective system for repair while the remaining portion of the system remains in operation.

Installing the Package Air Conditioners

Package units are factory assembled. After physically moving the unit into place plumbing and electrical connections are required. Both the plumbing and electrical work must conform to codes in force in the locality. The unit must be mounted level.

The motor-compressor is usually hermetic, but can be of the semihermetic, or open type. The refrigerant control is normally accomplished by a thermostatic expansion valve. The unit should be thoroughly checked for obvious damage which can occur during shipment. The air temperatures both in and out, the electrical load, and the operating pressures should be checked and recorded for future reference.

Servicing the Package Air Conditioner

Access to the internal parts of the unit are obtained by removing panels.

Periodic maintenance duties include replacing the filter or cleaning it, cleaning the evaporator coil and fins, cleaning the fan motor and oiling it unless it has sealed bearings, cleaning the drain pan and drain tube. The inner lining of the cabinet sometimes accumulates lint and it should be removed by vacuuming. It is also important to check the refrigerant charge, the operation of the thermostatic expansion valve, the water flow, etc.

QUESTIONS

1. How does the package air conditioner differ from a remote unit?

2. What are the three motors normally found on this unit?

3. What type of evaporator blower does this unit usually have?

4. Explain one method of capacity control on a unit with an air-cooled condenser?

5. What type of condenser is a shell and tube?

. What is the control used in a water-cooled condenser in the package unit to maintain head pressure?

What is the difference between a condenser water return line and a condensate water drain line?

REFERENCES

AFM 85-18, Maintenance and Operation of Refrigeration, Air Conditioning and Evaporative Cooling and Mechanical Ventilating Systems

Textbook, Trane Air Conditioning Manual

Textbook, Air Conditioning, Delmar

Textbook, Modern Refrigeration and Air Conditioning, Althouse, Turnquist, and Bracciano

DIRECT EXPANSION AIR CONDITIONING SYSTEMS

OBJECTIVE

When you have completed this unit of instruction on the 25-ton trainer, you will be able to:

* Locate, identify, and state the functions of safety controls and major components.

* Locate operational and capacity controls, state their functions, and adjust for proper operations.

* Use the hygrothermograph, an air flow instrument, a phychrometric chart and the 25-ton trainer to performa capacity check.

INTRODUCTION

The successful operation of radar equipment, communications networks, missile guidance, automatic data processing computers, and other applications require equipment cooling and ventilation systems which cannot stand wide temperature and humidity variations.

The control of temperature may be required to within ± 1° F, and the humidity tolerance within ± .5 percent. Relative humidity control usually allows a greater tolerance but must be low enough to minimize rust and corrosion while high enough to prevent static electricity charges from arcing.

To control the temperature, humidity, and ventilation in large equipment applications, many controls must be used to effect the desired conditions. Combinations of electrical, pneumatic, and electronic controllers, and controlled devices work as a unified team to produce the successful system operation.

The checking of system efficiency against designed performance data is just as important as checking the calibration and adjustment. In fact, it should be a primary consideration.

Compressor capacity control can be achieved in numerous methods--ranging from pressure switches to complex hydraulic systems, depending upon the system in use.

In all fields of air conditioning, the design conditions will have variable limits. The usual extreme conditions exist when the temperature is over 80°F or below 70°F, and if the humidity is less than 30 percent or more than 50 percent. Maintaining the exact range is often difficult but can be achieved with properly operating systems.

SAFETY PRECAUTIONS

Because of the important part safety plays in all subjects covered in this text, it will be listed first. However, it should be remembered that safety must be observed at all times.

In the first day of this course, you were given a briefing on ground safety. Review the study guide dealing with ground safety. You can find it in Study Guides AFS 54, 55, and 56. This study guide will apply primarily to electrical safety precautions.

As equipment becomes more complex so does safety consideration for both the operator and the equipment. You noted in this course that the equipment and controls became more complicated. Equipment cooling systems, especially for radar and missile sites, are very complex. Safety first is a must in working with all equipment cooling.

Operating Electrical Equipment

As a refrigeration and air-conditioning specialist, you may be required to operate equipment and controls with voltages ranging from 1 1/2 volts to 14,000 volts. When working near high voltage equipment, be extremely alert; don't guess; know what you are doing. If you become careless, you may end up a casualty or cause damage to expensive equipment.

There are things which you can do that will make your working conditions safe, but remember, even with switches and circuit breakers off, it is possible for you to get shocked through electrical feedback. Before you work on electrical equipment, turn the power off. It is extremely important to you to insure that the power is off and that the system is grounded in accordance with instructions contained in AFP 85-1.

Beware of the extremely high voltages in some missile sites. You can receive a shock without even making physical contact with electrical conductors or equipment. The electrician's handbook lists one foot as the minimum safe distance from circuits having operating voltages of 5,000 to 7,000 volts. If you get nearer than one foot, the voltage may arc over to you. The exact distance depends on the humidity, the surface upon which you are standing, the type of shoes you wear, and other factors.

If you have maintenance on electrical equipment with line voltage or above, call an electrician. He is responsible for repairing high-voltage circuits and equipment. Remember that the electrician may not be familiar with the equipment, controls, and circuits that you operate. Advise the electrician and help him check out the equipment once it is repaired. The electrician has been especially trained in the use of electrical safety equipment. Should you have to make emergency repairs, use all the safety equipment at your disposal.

Safety equipment is provided for working on electrical devices. This equipment consists of neon test lights, rubber gloves, rubber floor mats, and tools having insulated handles. Proper care and use of this safety equipment must be taken to insure its protective value.

Equipment Safety

Ground safety applies to the causes and prevention of accidents and first aid procedures which must be administered should a person become injured. Damage to material is also of major concern to the USAF. The loss of air conditioning in a site for 30 seconds may cause damage. Very delicate automatic controls keep spaces, computers, guidance systems, missiles, fuels, etc at the proper psychrometric condition so that when needed they will function properly. We love to tinker with switches, dials, thermostats, etc. We should not adjust and calibrate controls when we do not have sufficient training. In this block of instruction, you are to operate controls only when directed to do so by an instructor or a workbook. Equipment cooling machines are slaves to controls, and controls are slaves of the operator. Learn all you can about automatic controls and treat them gently. These controls, when properly calibrated and adjusted, will make your job easier.

FUNDAMENTALS OF DIRECT EXPANSION AIR-CONDITIONING EQUIPMENT

Direct expansion is a descriptive term. It describes the type of refrigeration system used. Evaporators are sometimes called expansion coils. When the evaporator cools the air, the system is called direct expansion. If a secondary refrigerant (brine or chilled water) is used to cool the air, the system is known as indirect expansion.

Expansion Valves

Most large air-conditioning systems use compressors with some type of capacity control. This capacity control is usually accomplished by holding one or more of the suction valves open when operating under reduced load. Unfortunately, the capacity of a thermostatic expansion valve cannot be controlled that easily. With the capacity of the expansion valve at a relatively constant value, it becomes oversized when the capacity of the compressor is lowered. However, within reasonable limits, a thermostatic expansion valve will adjust to a low-load condition and still maintain the required refrigerant control. Actually, smooth valve control is not necessary to reduce loads because full evaporator capacity is not required under these conditions.

When operating under reduced loads, the greatest refrigerant control problem is to prevent flood-back to the compressor. This flood-back problem can be solved by using an accumulator.

Good design and installation practices will insure the best possible control and minimize the danger of flood-back. It is very difficult to predict expansion valve performance at reduced capacities because of the many influencing factors such as design of the evaporator, location, and efficiency of the heat exchanger, suction line piping, bulb location, valve and distributor size and power element charge. Some systems operate very satisfactorily at 15 to 25 percent of full loads while other systems may cause trouble when the load reduces to 50 percent of capacity. During the design and fabrication of the system, if the following factors are observed, the system should operate at loads of 35 percent of capacity without difficulty. Figure [illegible] shows actual system design methods for split evaporator being fed by two TEVs. This system uses only two evaporators regardless of the number of cylinders in the compressor. The ability of an evaporator to operate at reduced loads will take care [illegible] 15- to 20-degree reduction. One of the solenoid valves is closed when the compressor capacity is reduced 50 percent. The evaporator and TEV operating have a capacity equal to the reduced capacity of the compressor.

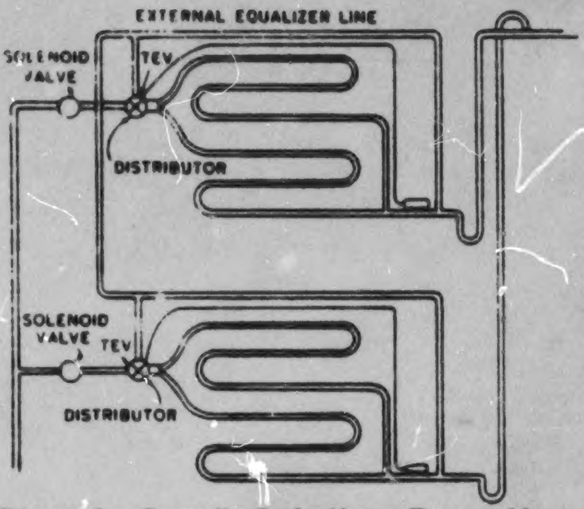

EXTERNAL EQUALIZER LINE
SOLENOID VALVE
TEV
DISTRIBUTOR
SOLENOID VALVE
TEV
DISTRIBUTOR

Figure 3. Capacity Reduction - Two or More Evaporators Handling the Same Load

Figure 4 illustrates the use of two thermostatic expansion valves and two distributors feeding one evaporator. Each evaporator circuit is fed by two distributor circuits, one from each distributor. The solenoid valves are actuated by the compressor modulation system.

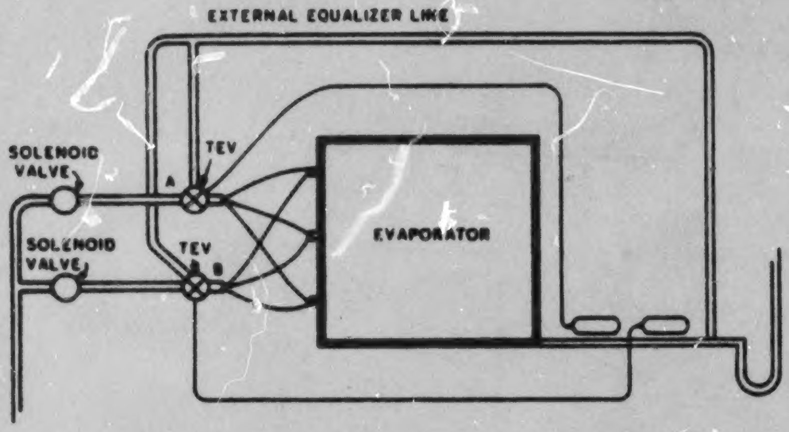

EXTERNAL EQUALIZER LINE
SOLENOID VALVE
TEV
A
EVAPORATOR
SOLENOID VALVE
TEV
B

Figure 4. Capacity Reduction - Single Evaporator Controlled With TEVs and Two Solenoid Valves

By sizing one solenoid valve, expansion valve, and distributor to handle approximately 67 percent of the load and the other to handle 33 percent, the following capacity reductions are possible:

Compressor Capacity	Valve A	Valve B	Distributor Loading	Evaporator Capacity
100%	Open	Open	100%	100%
83%	Open	Open	83%	83%
67%	Open	Closed	100%	67%
50%	Open	Closed	75%	50%
33%	Closed	Open	100%	33%
16%	Closed	Open	50%	16%

Table I

Figure 5 illustrates an arrangement similar to Figure 4 but without the use of solenoid valves. In this example, both expansion valve and distributors are the same size, and at full load both valves handle half of the load. However, expansion valve A is adjusted for a higher superheat than valve B. Under a high-load condition, valve B will not be able to maintain the low superheat to which it is adjusted. Valve A (with a higher superheat setting) will open and make up the deficiency in the capacity of valve B.

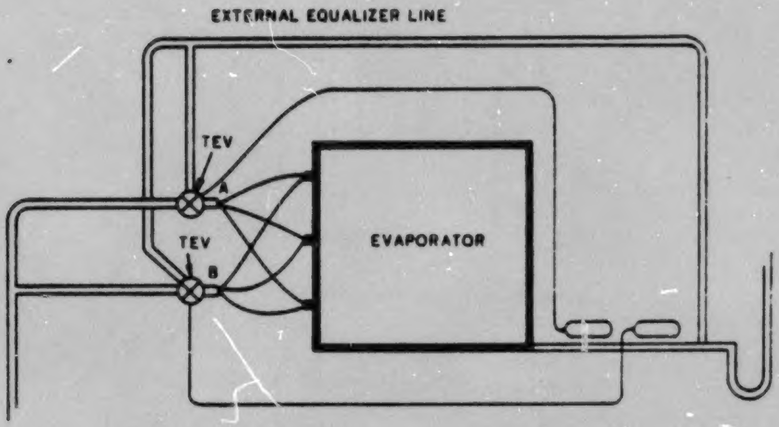


Figure 5. Two Thermal Expansion Valves (TEVs) Having Different Superheat Settings

When the compressor unloads to the point where valve B is able to handle the load alone, valve A will be forced closed by its higher superheat setting. The superheat at the evaporator outlet is then controlled solely by valve B with its capacity matched closely. This system is not recommended for low-temperature systems or any system where a close control of superheat is required, such as equipment cooling systems requirements.

Freeze Protector Thermostat

The feeler bulb for the freezestat is located in the airstream immediately following the cooling coil. This bulb senses the temperature of the air leaving the cooling coil. If the temperature drops below 30°F, the thermostat closes the solenoid valve in the liquid line, and the unit pumps down and cuts off on the low pressure motor control. The malfunction that caused the abnormal low temperature must be removed before restarting the unit.

Compressor

Due to the temperatures required and the size of the load, reciprocating compressors are usually used in this type application. If the load is large (over 40 tons) multiple compressors in parallel are often utilized. This allows the use of only one compressor when the unit is operating under a light load. Most small systems utilize a single multiple cylinder compressor with capacity control. This control allows the compressor to operate under a light load without cycling.

Complex Condenser System

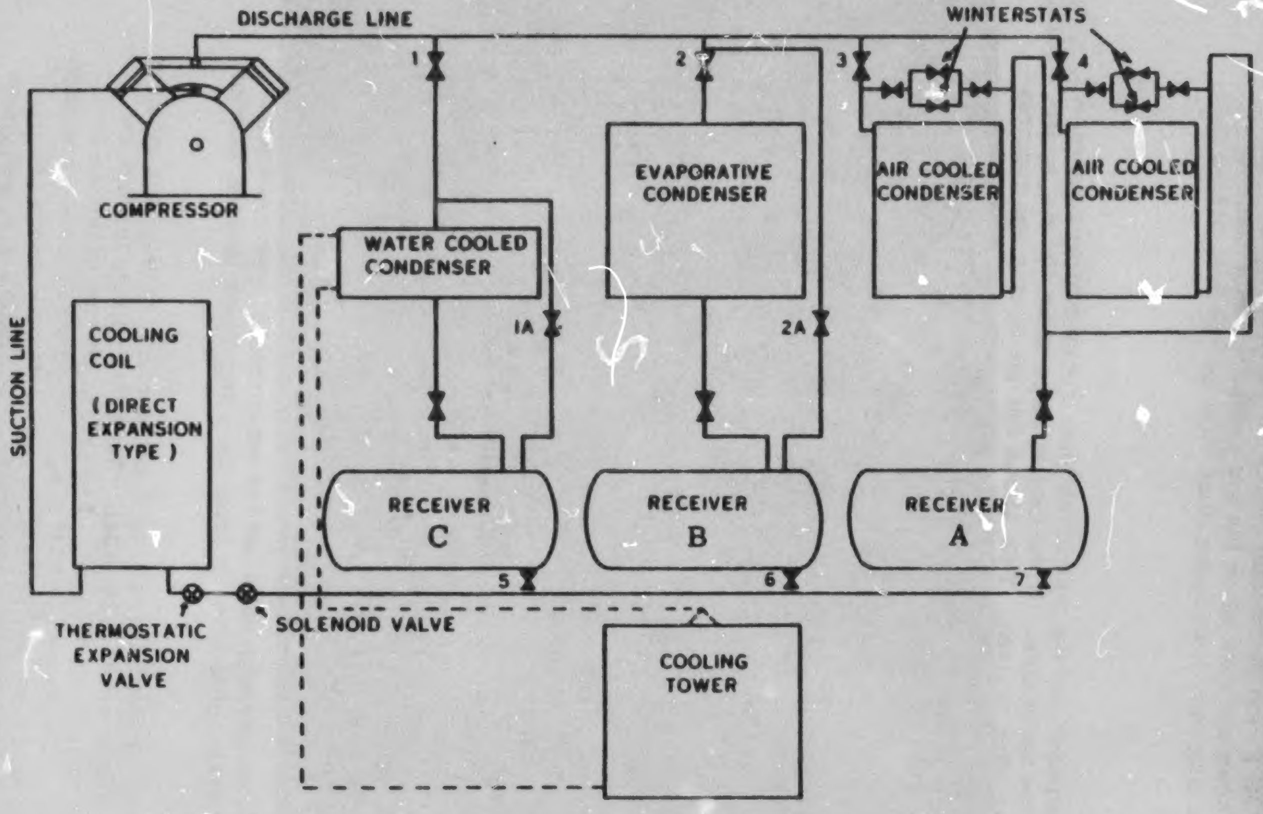
Equipment is cooled by giving up heat. This heat is rejected to the outside air through condensers. A complex condenser system consisting of air-cooled, evaporative-cooled and water-cooled condensers is indicated in figure 6. Study this system thoroughly as you will have to operate it.

AIR-COOLED CONDENSER OPERATION (See figure 6). The equipment cooling refrigeration system operates with air-cooled condensers as follows: numbered valves 3, 4 and 7 are open; all other numbered valves are closed. Hot high pressure refrigerant gas from the compressor passes through valves 3 and 4 and goes through both air-cooled condensers. There heat is removed from the hot gas changing its state to a warm high-pressure liquid refrigerant. The liquid refrigerant flows from the air-cooled condenser to the receiver. From the receiver, the warm refrigerant liquid moves through the line to the thermostatic expansion valve. In passing through the thermostatic expansion valve, it becomes a cold low-pressure refrigerant. The cold refrigerant flows through the DX coil picking up the heat that had previously been given up from the equipment in the cooled space. The heat ladened refrigerant now goes to the compressor where the cycle repeats itself over and over.

Water-Cooled Condenser

Most large commercial refrigeration units use the water-cooled type condenser. It is constructed so the refrigerant goes directly from the compressor into the interior of a tank or shell.

The shell-type condenser, or shell and tube as it is commonly called, is a cylinder made of steel with copper tubes inserted in the shell. Water circulates through the tubing and condenses the hot vapors into a liquid. The bottom portion of the shell serves as the liquid receiver. The advantage of this style of construction are compactness of design, the elimination of fans, and the need for separate condensers and receivers. Also it enables a flexible type of assembly. Two designs are used. One design has the water tubing coil inside the receiver. The other uses a number of straight tubes inside the receiver with water manifolds on both ends. When these manifolds are removed the water tubes can be easily cleaned of deposits which may reduce heat transfer.


DISCHARGE LINE
WINTERSTATS
1
2
3
4
COMPRESSOR
WATER COOLED CONDENSER
EVAPORATIVE CONDENSER
AIR COOLED CONDENSER
AIR COOLED CONDENSER
SUCTION LINE
COOLING COIL (DIRECT EXPANSION TYPE)
1A
2A
RECEIVER C
RECEIVER B
RECEIVER A
5
6
7
THERMOSTATIC EXPANSION VALVE
SOLENOID VALVE
COOLING TOWER

CMB-043

Figure 6. Complex Equipment Cooling Refrigeration System

Water-Cooled Capacity

The capacity of a water-cooled condenser is high due to good thermal contact between the cooling medium (water) and the refrigerant (R-12).

The transfer varies directly as the amount of water passed through the condenser. If the flow of water is fast, more heat will be removed, and if water flow is slow the heat removal will be less. To control how fast this water passes through the condenser a modulating type valve is usually installed. This modulating valve will open and close depending on the amount of heat to be removed to maintain a constant head pressure. By doing this we are controlling the capacity of the condenser.

Cooling Towers

In some localities water contains chemicals causing it to be unsuitable for use as a coolant. In other areas water may be scarce, expensive, or its use may be limited by law.

To permit using a water-cooled condenser and save on water consumption, water cooling towers are used.

These systems take the water from the condenser to the top of the tower. The top is pierced with holes allowing the water to fall down on wooden slats. Air is rushing through the wooden slats where some of the water is evaporated and the evaporation process cools the remaining water to the outdoor temperature or even below. The cooled water collects in the bottom of the tower and passes through a screen to remove leaves or other foreign material and is then recirculated back through the condenser by means of a pump. A float controlled valve in the lower water pan provides for make-up or refill water as needed. Chemicals may be and should be put in the water to prevent or retard rust formation, fungus growth and the like.

Cooling towers are made of corrosion resistant material such as steel zinc-dipped after assembly, copper, stainless steel,or wood treated to resist rot. Wood type cooling towers should never be painted as this will cause the wood to rot. Remember on startup of a wood cooling tower there will be a large amount of leakage until the wood swells and seals itself.

Evaporative Condenser

The evaporative condenser is a comparatively new arrival in the refrigeration field. However, there is nothing new in either its operating principles or construction. It combines into one unit two of the oldest pieces of refrigerating apparatus; the water-cooled condenser and the cooling tower.

The evaporative condenser (see figure 7) consists of a cooling tower with the wetted deck replaced by a condenser consisting of a coil of bare surface tubing. The water is pumped from the bottom of the tower to the top and sprayed over the coils. The hot gas from the compressor flows into the condenser where its heat evaporates the water that is being sprayed on the coils. Air is being drawn in at the bottom of the tower, pulled through the condenser where it picks up the heat which is expelled at the top. Evaporative condensers are very effective units. However, their use is limited to the same application as forced convection cooling towers; and, in addition, they should be located as near the compressor as possible.

Evaporative condensers consist of a housing, fan, condenser coil, water spray nozzles, water pump, and collecting pan. Some evaporative condensers are equipped with liquid receivers, liquid subcooling coils, and eliminators. (See Figure 7.)

INSTALLATION. Evaporative condensers are usually located outdoors or indoors adjacent to an outside wall. Condensers which are located outdoors are placed on a solid level concrete foundation or piers adjacent to the machinery room wall. Discharge air outlets direct the air away from the inlet air connection to prevent recirculation of the warm moist air back into the inlet duct.

Condensers installed indoors have the same foundation as those installed outdoors. They should be placed next to the outside wall so that the air inlet duct from the wall to the unit will be short. The size of the duct must never be smaller than the opening into the unit. The opening in the wall should be covered with a 1/4-inch mesh screen to prevent trash from entering the unit.

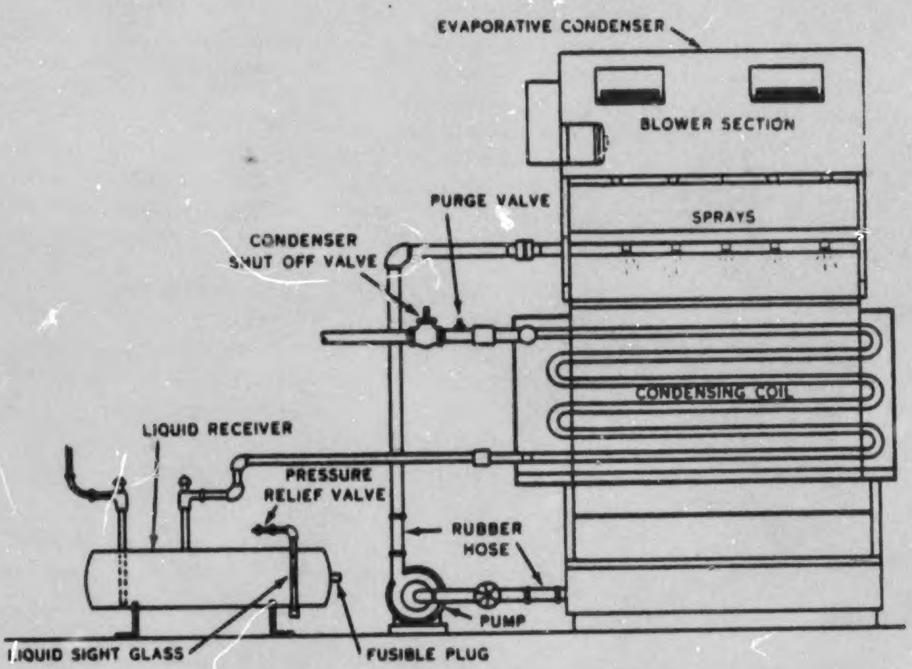

EVAPORATIVE CONDENSER
BLOWER SECTION
PURGE VALVE
SPRAYS
CONDENSER SHUT OFF VALVE
CONDENSING COIL
LIQUID RECEIVER
PRESSURE RELIEF VALVE
RUBBER HOSE
PUMP
LIQUID SIGHT GLASS
FUSIBLE PLUG

Figure 7. Diagrammatic Illustration of Evaporative Cooler

Sufficient space should be left on all sides of the condenser for servicing, cleaning, and general maintenance. Motors, drives, and electrical switches should be protected by the use of metal guards or hoods.

CAPACITY CONTROL. Good capacity control of an evaporative condenser is difficult because of the factors involved. As an example, assume the evaporative condenser is being used with a four-cylinder compressor. The compressor is equipped with cylinder unloaders. The evaporative condenser must be designed to handle the total heat load when all cylinders are loaded. As the load reduces and one or more of the cylinders unload, the evaporative condenser becomes oversize for that particular load. When the compressor is operating with only one cylinder loaded, over-condensing will occur and there may be some flashing of the liquid refrigerant in the liquid line.

Following are four general methods of capacity control used on evaporative condensers:

Modulating Dampers. This is the best method of capacity control. As the head pressure varies, the damper opens or closes, allowing more or less air to pass through the unit. The damper should completely close each time the compressor cycles. This will eliminate the possibility of air passing through the unit by natural convection and reducing the head pressure excessively during the off cycle.

Cycle the Water Flow. When the head pressure drops below a predetermined point the pump water stops and the unit acts as an air-cooled condenser until the head pressure builds up to the desired pressure. This is a very good method of capacity control but it has one disadvantage; it causes scale formation. Each time the water stops, the water left on the coils evaporates and leaves a thin coat of minerals and scale on the coil. There is very little mineral left after each cycle; but, after a period of time, it does build up excessively. Allowing the water to flow as continuously as possible reduces this scale formation.

Cycle the Fan. When the head pressure drops below a predetermined point, the fan stops. The water continues to flow, and the moist air is carried off by natural convection only. The cooling coils must be quite large, or the fan will have a tendency to short cycle.

Two-Coil Condenser. The condenser is divided into two parts. When the head pressure drops below a predetermined point, a solenoid valve closes cutting off one of the condenser coils. The unit continues to operate on one coil only.

MAINTENANCE. For satisfactory operation of evaporative condensers, there must be an unrestricted flow of air through the system. The inlet and outlet openings must be free and unrestricted. Check these areas to make sure that trees, vegetation, boxes, or crates do not obstruct the airflow. The inlet louvers and screen must be checked and cleaned periodically.

Waterflow is very important. The pump inlet screens and spray nozzles should be cleaned weekly. Once each month the condenser coils, spray chamber, and collecting pan should be scrubbed with a brush and flushed with water. Once each year the condenser should be dismantled and inspected. All worn or damaged impellers must be replaced. The bearings in all pumps, fans, and motors must be checked and replaced if necessary.

A good water analysis and treatment program must be established and maintained. This will keep scale, corrosion, and algae from becoming a problem.

CHANGING CONDENSER OPERATION. In changing from one condenser to the other (figure 8) five steps are involved.

1. Close the hot gas valve(s) of the old system.

2. Open the hot gas valve(s) of the new system.

3. Operate on the new system until pump down is completed.

4. Close king valve of the old system.

5. Open king valve of the new system.

Assume that we are operating the system on air-cooled condensers and desire to operate with the evaporative condenser. Assume also that all of the refrigerant is in the receiver of the air-cooled condenser. According to the five steps above, we would close valves No. 3 and No. 4, and open valve No. 2 and valve No. 2A. Then we would operate the system using the evaporative condenser until the unit pumped down and shut off. During this operation, we were removing refrigerant from receiver "A" and placint it in receiver "B." All we have to do now is close king valve No. 7 and open king valve No. 6. The system will automatically start up and operate.

To operate on the water-cooled condenser from the evaporative condenser:

1. Close valves No. 2 and No. 2A.

2. Open valves No. 1 and No. 1A.

3. Operate system on water-cooled condenser until pump down.

4. Close valve No. 6.

5. Open valve No. 5. The system is now operating on water-cooled condenser.

Starting the System

To start the air handler motor, close the air handler manual circuit breaker lever and press the start button. The air handler will start.

To start the compressor, close the compressor manual circuit breaker lever and close manual switch S-2. The compressor will start. There are no physical connections between S-2 and the compressor, yet it is this manual switch which allows the compressor to start. The reason for this is that on large units of this type, we pump down the system on shutdown by closing the refrigerant solenoid valve. With no refrigerant going up to the compressor, the suction pressure will reduce to the setting of the low pressure (LP) motor control. This will open the LP contacts. When the LP motor contacts open, the compressor starter holding coil will deenergize, opening the compressor main contacts and stopping the compressor. When starting the compressor with the S-2 closed, the solenoid valve will open allowing refrigerant vapor to flow to the

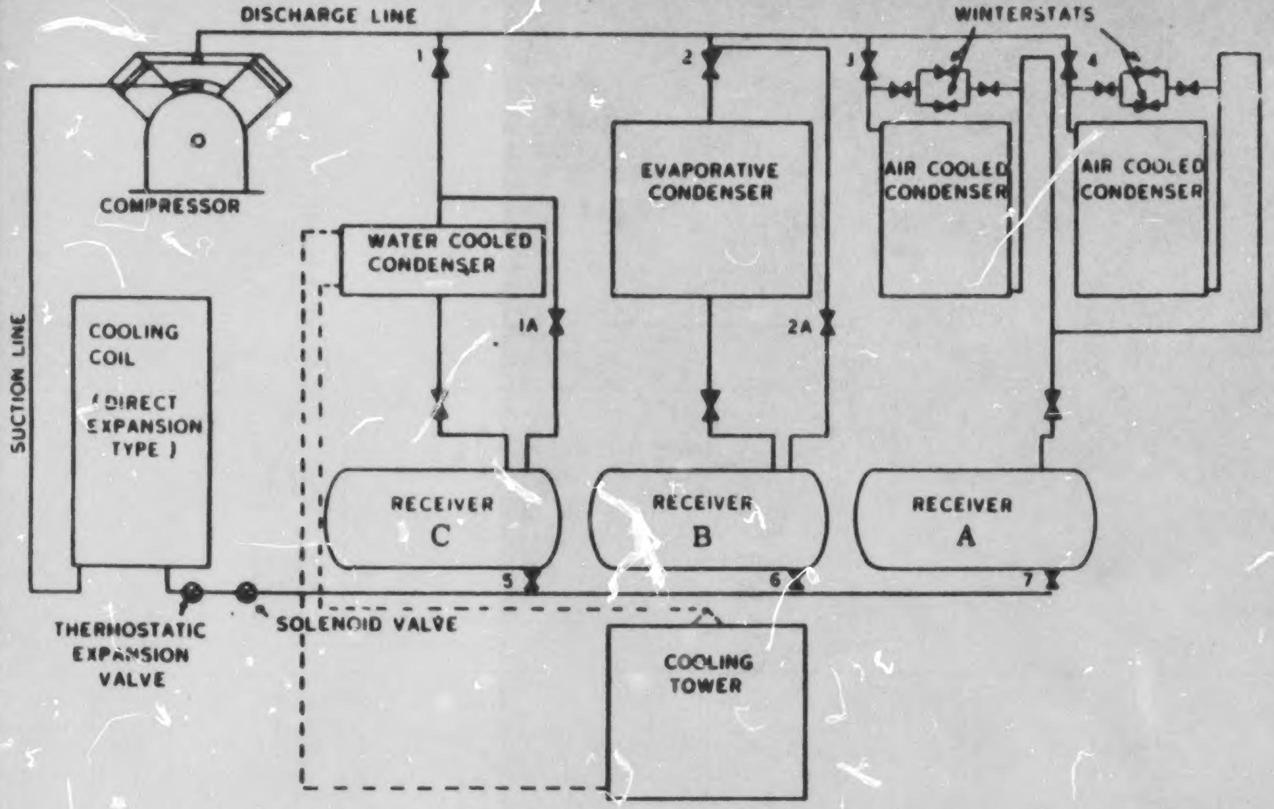

DISCHARGE LINE
WINTERSTATS
1
2
3
4
COMPRESSOR
EVAPORATIVE CONDENSER
AIR COOLED CONDENSER
AIR COOLED CONDENSER
WATER COOLED CONDENSER
SUCTION LINE
COOLING COIL (DIRECT EXPANSION TYPE)
1A
2A
RECEIVER C
RECEIVER B
RECEIVER A
5
6
7
THERMOSTATIC EXPANSION VALVE
SOLENOID VALVE
COOLING TOWER

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Figure 8. Complex Equipment Cooling Refrigeration System

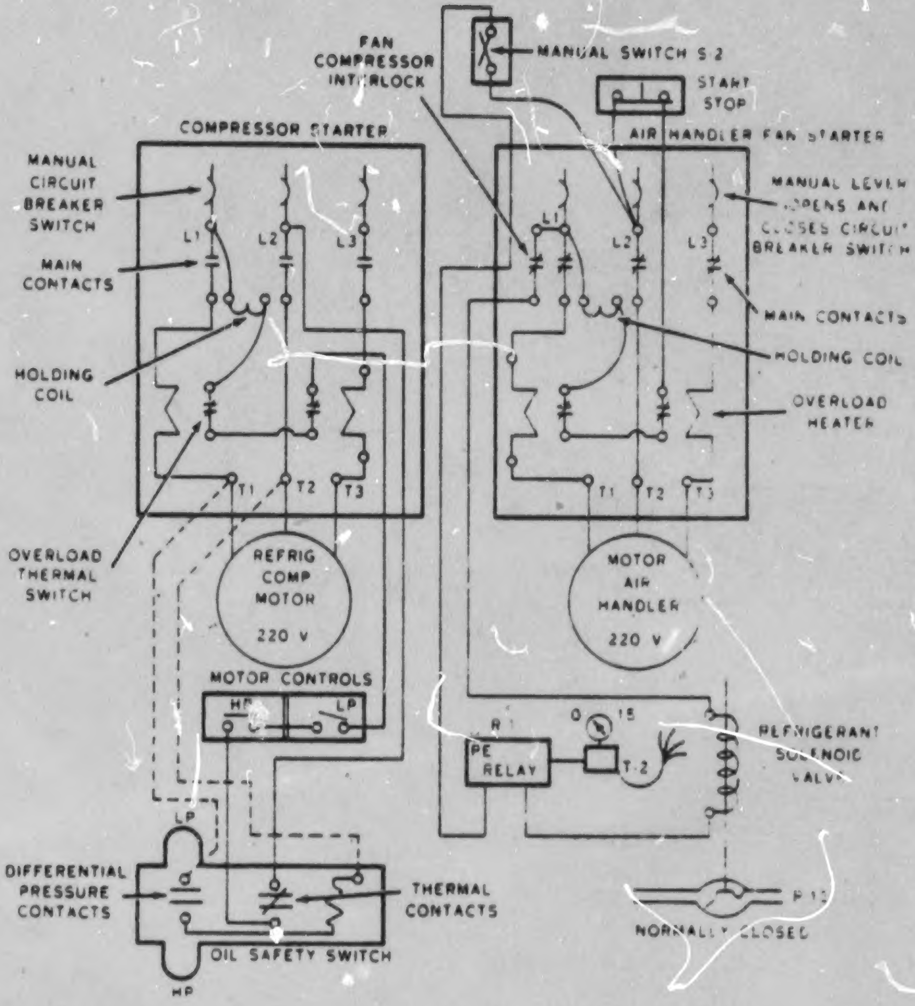

FAN COMPRESSOR INTERLOCK
MANUAL SWITCH S-2
START
STOP
COMPRESSOR STARTER
AIR HANDLER FAN STARTER
MANUAL CIRCUIT BREAKER SWITCH
MAIN CONTACTS
HOLDING COIL
OVERLOAD THERMAL SWITCH
L1
L2
L3
T1
T2
T3
MANUAL LEVER OPENS AND CLOSES CIRCUIT BREAKER SWITCH
MAIN CONTACTS
HOLDING COIL
OVERLOAD HEATER
REFRIG COMP MOTOR 220 V
MOTOR AIR HANDLER 220 V
MOTOR CONTROLS
HP
LP
R-1
PE RELAY
0
15
T-2
REFRIGERANT SOLENOID VALVE
R-1
NORMALLY CLOSED
LP
DIFFERENTIAL PRESSURE CONTACTS
THERMAL CONTACTS
OIL SAFETY SWITCH
HP

Figure 9. Wiring Diagram of Equipment Cooling System

compressor. The low-pressure motor control, in sensing increased refrigerant vapor pressure, will close. The holding coil will energize, closing the main contacts and the compressor will start.

Safety Controls

The HP and LP motor controls, oil safety switch, and overload thermal switch are in series with each other and with the compressor holding coil. Should a condition exist to open any of these safety controls, the holding coil will deenergize opening the main contacts and the compressor will immediately stop. All of these controls are located on the left side of figure 9. There will be no pump down of the system when any one of the controls on the left side of figure 9 opens.

On the right side of figure 9, manual switch S-2, PE relay R-1 in conjunction with multi-insertion thermostat T-2 and fan-compressor interlock are in series with each other. Power is provided between L1 and L2. Should one of these controls open, the refrigerant solenoid valve will close and the compressor will pump down and stop. It is easier to understand this circuit if you start at L1 and stop at L2. For example, assume that the air handler motor stopped. The air handler main contacts, including the fan-compressor interlock, will open. With the fan-compressor interlock contacts open, power is cut off to the refrigerant solenoid valve. The compressor will then pump down and stop. Study the diagram in figure 9; it will help you understand the operation of the system and will make troubleshooting easy for you.

EQUIPMENT COOLING ELECTRICAL CONTROLS

Safety Precautions

Many factors affect the safety of personnel and of delicate controls during operation and maintenance of air-conditioning equipment. A few precautions follow:

1. Do not wear rings or jewelry when working on electrical equipment.

2. Do not adjust electrical controls unless you are checked out and authorized to do so.

3. In this block of instruction, touch controls only when directed to do so by your instructor.

4. Beware of electrical feedback in electrical control circuits.

5. Review AFM 127-101, Industrial Safety Accident Prevention Handbook.

Application of Series 90 Control

It is often desirable to control the temperature of an equipment cooling space by controlling the amount of air that circulates across a direct expansion (DX) coil. Figure 10 is a diagram of this application.

When the room temperature cools below the set point, the room thermostat wiper moves toward the blue lead B. This causes more current to flow in the right circuit of the resistance bridge energizing the CCW winding of the face and bypass damper motor. The face damper will close and the bypass damper open until the resistance bridge circuits are again in balance.

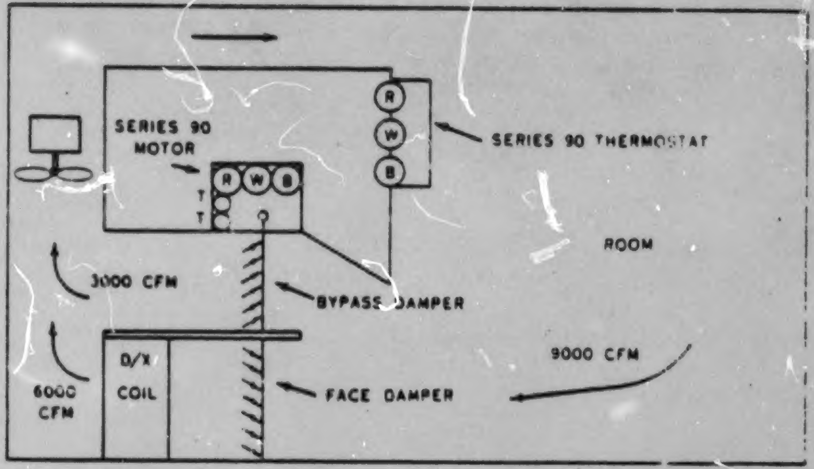


Figure 10. Face and Bypass Damper Temperature Control

High Limit Humidistat

In most equipment cooling systems, we do not control humidity at a specified figure, but are given a high limit such as 50 percent which we must not exceed. This can be accomplished very easily by inserting a series 90 high limit humidistat in a basic series 90 circuit (see figure 11).

Suppose that the maximum humidity allowed in the equipment cooling system is 50 percent, and the thermostat is set with the face and bypass half open. As long as the humidity remains below 50 percent, the humidity pot wiper will remain at 1. When the humidity in the room goes above 50 percent, the humidistat hair will become longer, causing the humidistat pot wiper to move towards 2. This movement adds more resistance to the right series 90 circuit. More current will flow through the clockwise relay winding; the damper motor will turn clockwise, opening the face damper. With more air going over the DX coil, more moisture will be removed from it, and eventually the room humidity will decrease. The high-limit humidistat will override the thermostat and cause the face damper to open more than the thermostat wants it to. Naturally, if the face damper is open more than the thermostat is calling for it to open, the room temperature will drop below the desired value. This is corrected by adding a reheat steam or hot water coil operating on command of a second pot in the room thermostat. A complete system is shown in figure 12. This system will maintain both the temperature and humidity within the limits of an equipment cooling system. Figure 13 shows the wiring that would have to be accomplished by a refrigeration specialist in connecting the complete control system.

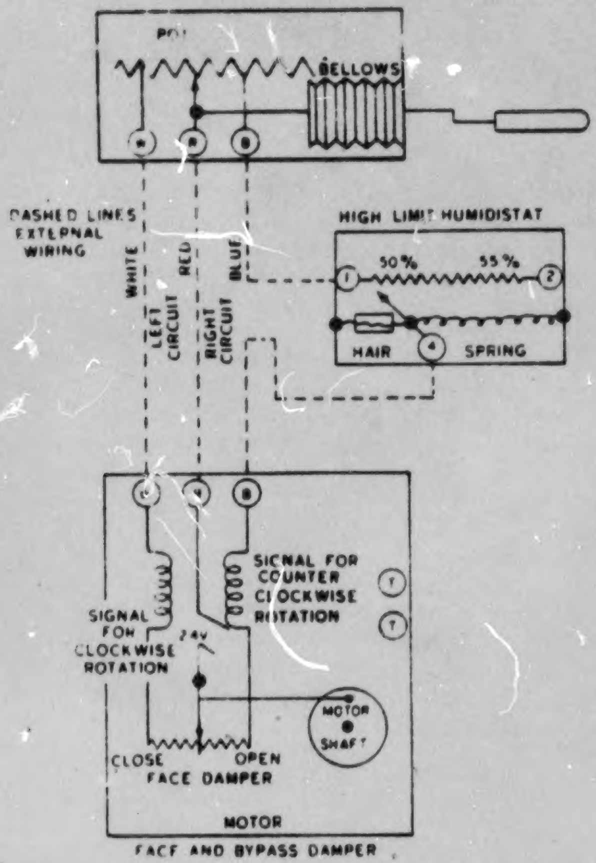

POT
BELLOWS
DASHED LINES EXTERNAL WIRING
WHITE
RED
BLUE
LEFT CIRCUIT
RIGHT CIRCUIT
HIGH LIMIT HUMIDISTAT
50%
55%
HAIR
SPRING
SIGNAL FOR COUNTER CLOCKWISE ROTATION
SIGNAL FOR CLOCKWISE ROTATION
24V
MOTOR SHAFT
CLOSE
OPEN
FACE DAMPER
MOTOR
FACE AND BYPASS DAMPER

Figure 11. Series 90 High Limit Humidity Control

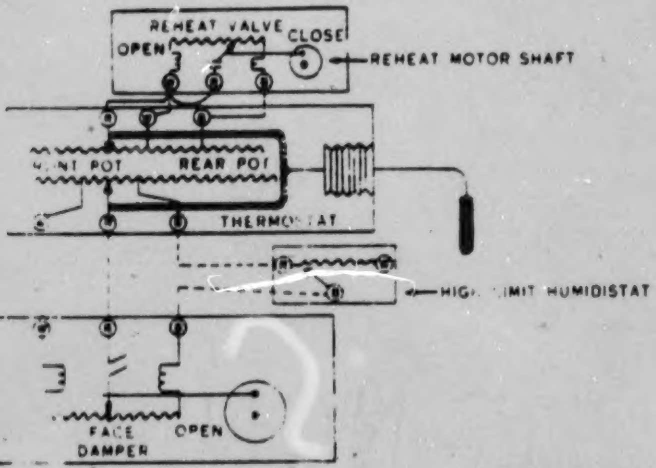

REHEAT VALVE
OPEN
CLOSE
REHEAT MOTOR SHAFT
POT
REAR POT
THERMOSTAT
HIGH LIMIT HUMIDISTAT
FACE DAMPER
OPEN

Figure 12. Complete Temperature and High Limit Humidity Control

A schematic of a typical equipment cooling system is shown in figure 13. The thermostat controls the temperature of the air in the equipment cooling space. This is done by modulating the face and bypass dampers. The face and bypass dampers are so arranged that they operate opposite each other. When the face damper is opening the bypass damper is closing. The face damper will be 1/4 open when the bypass damper is 3/4 open. When the temperature is at set point, both face and bypass dampers will be in the half position. Half position can be called either half open or half closed. When the space becomes warmer than the set point of the thermostat (76°F in this example), the thermostat will signal the damper motor to open the face damper slightly more than 1/2. Opening this damper will cause more air to pass over the direct expansion cooling coil. The supply air will become cooler, thereby lowering the room temperature back to 75°F.

With the space temperature at 75°F, the thermostat directs the face damper to be exactly 1/2 open. Now let us assume that the humidity in the equipment cooling space goes above the high limit set point of 50 percent to 51 percent. The high limit humidistat (H-1) will override the thermostat and command the face damper to open more than 1/2. The DX coil, having a mean surface temperature (apparatus dewpoint) of about 40°F, will remove more grains of moisture from the circulating air and in time will lower the space relative humidity.

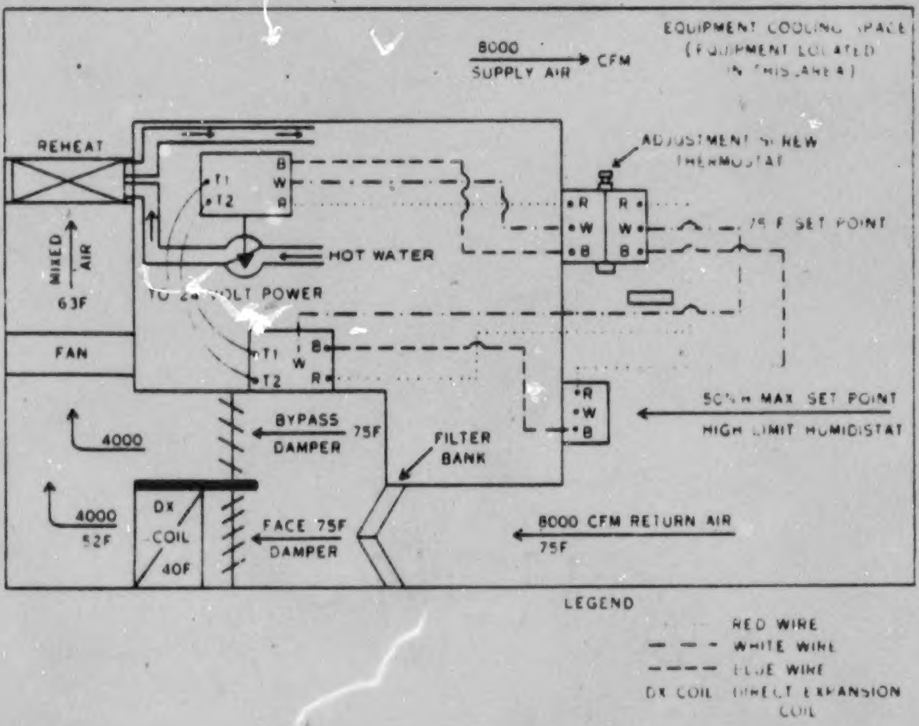
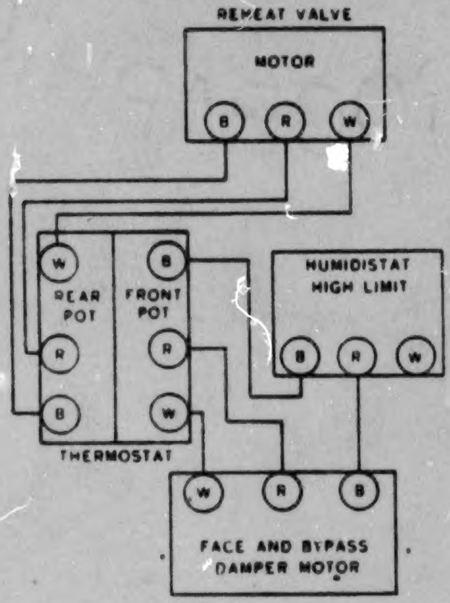

EQUIPMENT COOLING SPACE
(EQUIPMENT LOCATED IN THIS AREA)
8000
SUPPLY AIR
CFM
REHEAT
ADJUSTMENT SCREW
THERMOSTAT
T1
T2
B
W
R
75 F SET POINT
HOT WATER
MIXED AIR
63F
TO 24 VOLT POWER
FAN
50% H MAX SET POINT
HIGH LIMIT HUMIDISTAT
4000
BYPASS DAMPER
75F
FILTER BANK
4000
52F
DX COIL
40F
FACE 75F DAMPER
8000 CFM RETURN AIR
75F
LEGEND
RED WIRE
WHITE WIRE
BLUE WIRE
DX COIL DIRECT EXPANSION COIL

Figure 13. Schematic of a Typical Equipment Cooling System

Because the humidistat opened the face damper more than the thermostat wanted it to, the space temperature will drop below 75°F. In this case the thermostat directs the reheat coil to furnish heat to the supply air so that the space will be exactly 75°F.

In summing up the actions of the thermostat and humidistat, the thermostat controls the face and bypass dampers and reheat coil. The humidistat has more authority than the thermostat in controlling the face and bypass dampers and can override the thermostat in causing the face damper to open wider than usual. The humidistat has no control of the reheat coil. In this manner, both temperature and maximum humidity requirements can be maintained in an equipment cooling space.



NOTE ALL WIRING SHOWN IS 24V AC

Figure 14. External Wiring of Temperature and High Limit Humidity Control System

EQUIPMENT COOLING PNEUMATIC CONTROLS

Bleed Type Pneumatic Controls

Control terms have not been standardized in the Air Force or the air-conditioning industry although some attempts have been made to do so. In this study guide the following terms will apply.

Supply and Main air refers to the air which is furnished to the controller.

Control and Branch air refers to the air which leaves the controller and goes to the valve or damper.

Pneumatic-electric relay refers to an air actuated device which causes electric contacts to make or break.

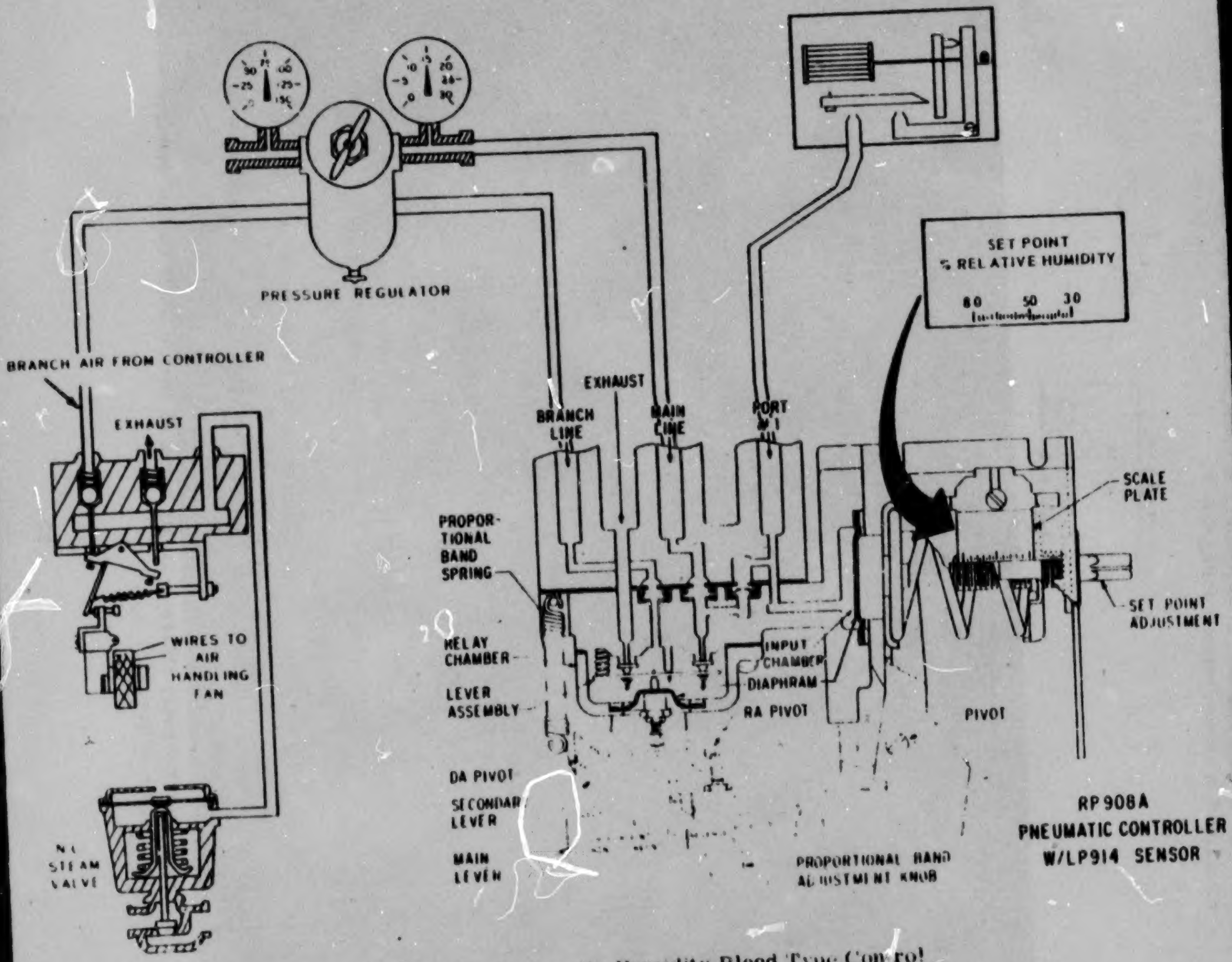

PRESSURE REGULATOR
BRANCH AIR FROM CONTROLLER
EXHAUST
WIRES TO AIR HANDLING FAN
N.C. STEAM VALVE
SET POINT % RELATIVE HUMIDITY
80 50 30
EXHAUST
BRANCH LINE
MAIN LINE
PORT #1
PROPORTIONAL BAND SPRING
RELAY CHAMBER
LEVER ASSEMBLY
DA PIVOT
SECONDARY LEVER
MAIN LEVER
INPUT CHAMBER
DIAPHRAM
RA PIVOT
PIVOT
PROPORTIONAL BAND ADJUSTMENT KNOB
SCALE PLATE
SET POINT ADJUSTMENT
RP 908A PNEUMATIC CONTROLLER W/LP914 SENSOR

Figure 15. Pneumatic Humidity Bleed Type Control

Electric-pneumatic relay refers to an electrically actuated device which allows air from a controller to reach the valve it is controlling.

Other control terms have been defined for you in Block VII of this course.

Operation of the bleed type pneumatic control can best be explained by referring to figure 15. The restrictor orifice in the pneumatic line is adjusted so that it is smaller than the nozzle opening. This allows the branch line pressure to vary between 3 and 15 psi, depending on the position of the flapper.

When you refer to the bleed control (Fig. 15), assume that the room humidity increases. Moisture will cause the hair in the humidistat to expand and move the flapper away from the nozzle. This movement allows a greater amount of air to bleed at the nozzle which, in turn decreases the branch line pressure.

Since the branch line pressure to the normally closed (NC) pneumatic steam valve has decreased, the valve will move toward the closed position. This movement decreases the amount of steam which is fed into the room. Thereby decreasing its relative humidity.

When the humidity in the room decreases, the reverse of that described in the preceding paragraph takes place.

Pneumatic-Electric Relays

Pneumatic-electric relays are used in a number of applications. A common application is shown in figure 16. Branch line air from a controller closes a set of contact points (figure 16) which allows a refrigerant solenoid valve to open. When the branch line air pressure reduces to some predetermined amount, the electric relay contacts open and the refrigerant solenoid valves close. On the 25-ton system this is the function of the gradustat (or freezestat). As long as the pressure being sensed is above the cutout pressure, pressure is applied to the bellows maintaining a closed circuit in the P-E relay, which insures the solenoid valve is open. If the pressure decreases the series circuit is broken, closing the solenoid valve and causing the system to cut out on LPMC.

Electric-Pneumatic Relay

The controller branch line air routes through the electric-pneumatic relay. For this reason the controller in figure 17 is in command of the steam valve only when the air conditioner fan is on. This is a safety precaution, for if the air-conditioner fan should stop due to an electrical trouble, steam for humidification to the room will be shut off as air to the valve is bled off to the atmosphere.

Adjustment of Pneumatic Controllers

As with the electrical controllers, pneumatic controllers can also be calibrated in five easy steps as follows:

M - Minimum - With humidistat at full bleed, adjust restrictor to 3 psi.

C - Center the branch pressure to 1/2 of main line pressure.

O - Observe the humidity at the wood element (use instrument).

A - Adjust the scale plate to the humidity observed in the preceding step.

S - Set the humidity (set point) needle to the desired humidity.

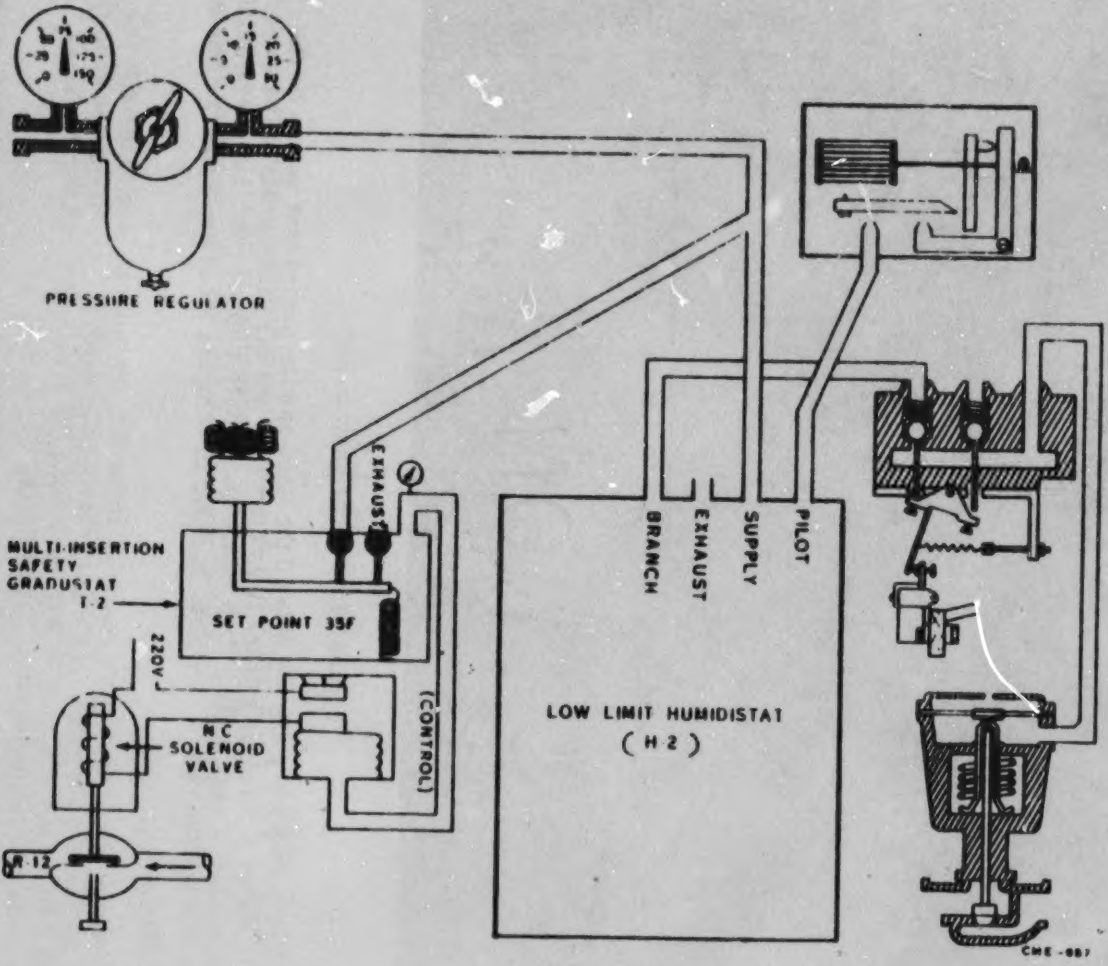

PRESSURE REGULATOR
EXHAUST
MULTI-INSERTION SAFETY GRADUSTAT T-2
SET POINT 35F
220V
N C SOLENOID VALVE
R-12
(CONTROL)
BRANCH
EXHAUST
SUPPLY
PILOT
LOW LIMIT HUMIDISTAT (H-2)
CME-087

Figure 18. Complete Humidity Control Loop

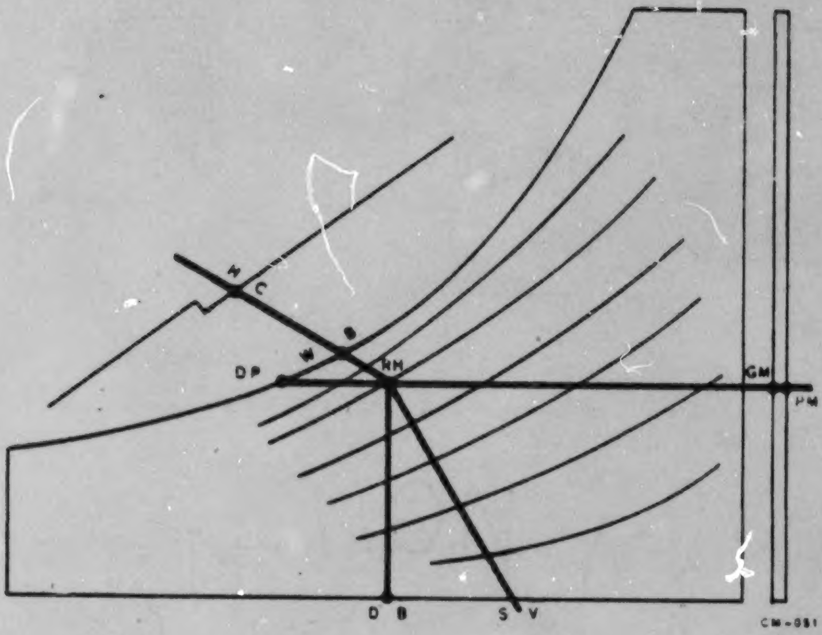


Figure 19. Psychrometric Plot

In a previous study guide we defined the lines and the scales that we use on the chart. Figure 19 shows a composite of the lines discussed and the relationship of the various lines and scales to each other. This figure shows only a single plot, but psychrometric analysis will involve two to four plots in order to compare all of the temperatures and properties.

To have a good comparative analysis of the air, we must be able to identify the various names given to the air as it goes through the system. Air at outside conditions is called Outside Air (OA). It is introduced into the system through the ducts and various plenums, taking on other names during its travels.

Supply Air (SA) is the air that is cooled to the final desired condition and supplied to the controlled space. As it is recirculated into the return duct, it becomes Return Air (RA). If the air is to be exhausted to offset the OA brought in, then the air exhausted is labeled as Exhaust Air (EA). If any of the air types are mixed in a mixing plenum, then the name given to the air following this process is Mixed Air (MA). All of these situations can be plotted. Mixed air will be covered later.

Psychrometric Problems

In solving psychrometric problems, we will plot the conditions of the air passing through the system. To graphically illustrate the conditions of the air at given points, we must identify a few more terms that will apply in this analysis. Some of the terms include the following:

- Grains of Moisture Removed
- Pounds of Moisture Removed
- Total Btu Removed
- Sensible Btu Removed
- Latent Heat Btu Removed
- Coil Slope
- Room Slope
- Apparatus Dewpoint
- Mixed Air Plots

NOTE: In psychrometrics, all values on the chart are per pound of dry air.

GRAINS OF MOISTURE REMOVED. This quantity is found by subtracting the GM of the smaller plot considered from the GM of the larger plot being considered.

For example if the RA plot contained 98 GM and the SA plot contained 77 GM, subtract 77 from 98 and the difference would be 21 GM removed.

POUNDS OF MOISTURE REMOVED. This amount would be determined by the same procedure. If the RA plot contained .014 lb and the SA plot contained .0076 lb, subtract .0076 from .014 and the difference would be .0064 pounds of moisture that were removed.

HEAT CONTENT REMOVED. This can be found by subtracting the HC of the smaller plot from the HC of the larger plot and the difference would be the Btu heat content difference. Earlier in this course you learned that total heat is sensible heat plus latent heat. Therefore, when necessary, the total heat removed can be separated into specific amounts of sensible heat and latent heat.

Sensible heat is heat that changes the temperature of a substance but not its state. Latent heat is heat that changes the state of a substance but not its temperature. When applied to water, sensible heat changes the temperature of the water but it remains water. Latent heat changes water at 212°F to steam at 212°F, thereby changing its state from a liquid to a vapor but with no change of temperature. Sensible heat is measurable with a thermometer; latent heat is not. In air-conditioning work, latent heat is involved only by the addition or removal of moisture in the air. The psychrometric chart is the only tool you have to calculate latent heat.

The total heat removed by an air conditioning unit is simple to calculate on a psychrometric chart. You begin by determining both the dry bulb and wet bulb temperature of the supply air and the return air. Plot both dry bulb temperatures on the chart, as shown in figure 20. Then, plot the wet bulb temperatures and extend their lines through the heat content scale. The total heat removed is the difference between the Btu readings taken at the intersection points of the WB lines with the heat content scale. For example, as shown in figure 20, 34 minus 15 equals 19 Btu of heat removed.

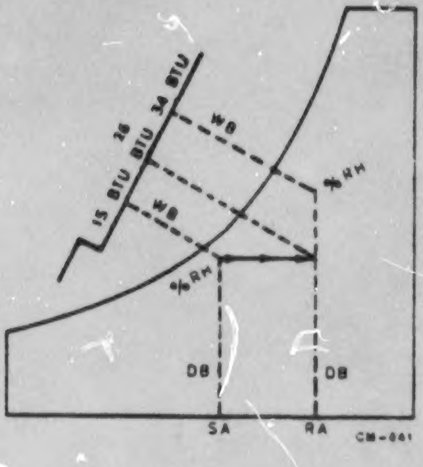


Figure 20. Heat Removal Plots

When necessary, you can determine how much of the heat removed is sensible heat and how much is latent heat. To determine sensible heat, draw a horizontal line from the % RH point for SA until it intersects with the RA line as shown in figure 20. From this point of intersection, draw a line parallel to the WB lines to the heat content scale. The difference in the Btu readings at this point and the SA wet bulb line is sensible heat. As shown in figure 20, 26 minus 15 equals 11 Btu of sensible heat. Latent heat is the total heat minus sensible heat. Following through, this is 19 minus 11, giving a latent heat content of 8 Btu.

COIL SLOPE. This is the amount of Btu removed from the air entering and leaving a coil. To graphically illustrate coil slope, you must join the % RH points of the TE and the TL with a straight line, and read the answer on the HC scale by subtracting the HC of TL from the HC of TE (see figure 21).

ROOM SLOPE. This is the amount of Btu that are picked up in a room from the time air enters as supply air and leaves as return air. Plotting procedures are the same as for coil slope; join the % RH of TE and the TL with a straight line and read the answer on the HC scale by subtracting the HC of SA from the HC of RA and recording the difference (see figure 21).

APPARATUS DEWPOINT. This is the temperature of the cooling coil. The term apparatus dewpoint refers to the cooling coil of an air-conditioning system. To plot apparatus dewpoint, join the % RH of TE of the coil and the TL of the coil and extend the straight line to the saturation curve and read the temperature at the point of intersection. Most manufacturers design their units with coils to be maintained at 40°F. to prevent freezeup of the coil.

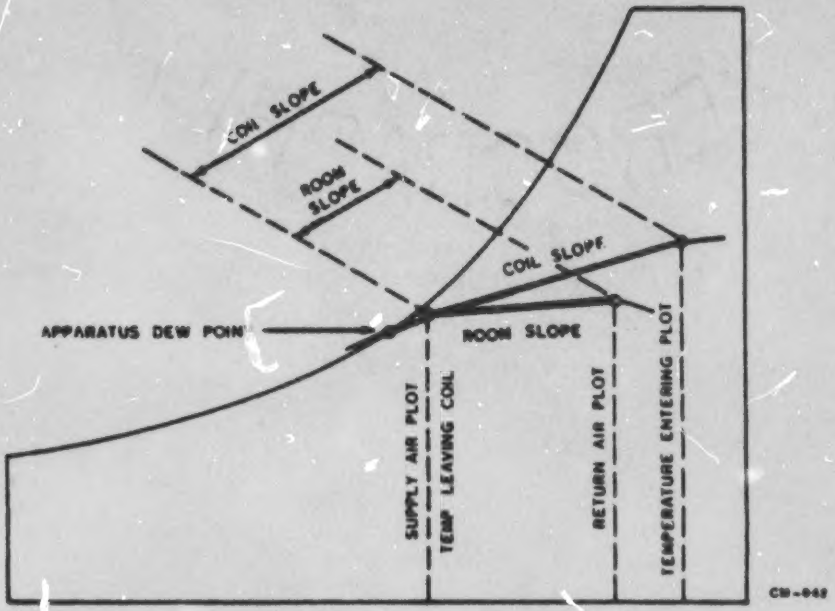

COIL SLOPE
ROOM SLOPE
COIL SLOPE
APPARATUS DEW POINT
ROOM SLOPE
SUPPLY AIR PLOT
TEMP LEAVING COIL
RETURN AIR PLOT
TEMPERATURE ENTERING PLOT

Figure 21. Coil Slope, Room Slope, and Apparatus Dewpoint

Figure 22 shows the air movement through the system that you will operate. Note that the air goes through the face damper, or through both at the same time. When making a capacity check of the cooling coil, the CFM going over the coil must be known. By closing the bypass damper completely, 10,000 CFM may be used as this is the output of the fan shown at B.

A. Swirling plates
B. Fan section
C. Steam load coil section
D. Hot water load coil section
E. Cooling coil section
F. Face and bypass dampers
G. Filter section
H. Steam reheat coil section
I. Steam jet humidifier
J. Pitot tube openings
K. Hot water reheat coil section
L. Test cabinet area
M. The controls mounted on the left side of the unit
N. Freeze protector

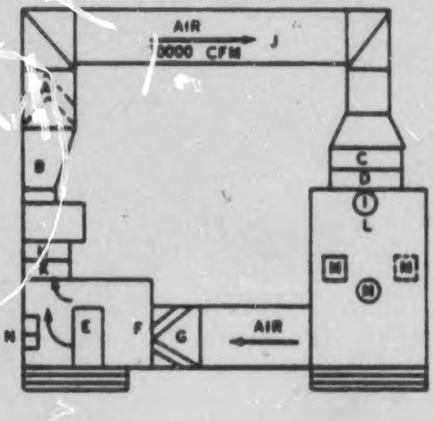

AIR
10000 CFM
J
B
C
D
I
L
M
M
M
K
N
E
F
G
AIR

Figure 22. Air Movement Through 25-Ton System

APPLICATION OF TEMPERATURE AND RELATIVE HUMIDITY CONTROLS

Applications of automatic control systems range from simple domestic temperature regulation to precision control of industrial processes. Automatic controls can be used wherever a variable condition must be controlled. That condition may be pressure, temperature, humidity, or rate and volume of flow; and it may exist in a liquid, a solid, or a gas.

In the following paragraphs, we will see an application of controls. These controls are employed to maintain the relative humidity and temperature in a space.

Control of Temperature and Relative Humidity (RH)

CONTROLS. The controls used for control of the system consist primarily of Room Thermostat T-1 and Humidistat H-1. The compressor capacity control has been adjusted so that all the cylinders are loaded. The bypass dampers are closed as indicated, and the reheat coil is closed. The maximum sensible and latent heat load possible has been placed on the system to produce a room condition of 75° F and 50 percent RH.

CONTROL ADJUSTMENT. Place the normal room load on the system. In this example probably 15 tons. Adjust the set point of thermostat T-1 to 75°F and high limit humidistat H-1 to 50 percent maximum. Adjust the capacity control (Cylinder Unloaders) so that one cylinder will be unloaded when the ADP is 40°F. Observe the operation of the system and trim the controls, as necessary, to maintain the desired room conditions.

COMPRESSOR CAPACITY CONTROLS

Equipment Application

Assume that a theater has a maximum heat load of thirty tons. The equipment must be large enough to handle this load. However, what happens when the heat load is reduced to only five tons? The equipment is now so oversized that it will cut in and out very rapidly. This is called short cycling which can damage the system. Short cycling can be reduced by increasing the differential, the difference in degrees between the cut-in and cut-out of the system. However, increasing the differential will cause the temperature to become too high before the system cuts in and too low before it cuts out. Problems of this type can be solved in several ways. Some of the possible solutions are:

1. Install six 5-ton air-conditioning units. In this case, the temperature can be controlled by turning units on or off as the load varies. This solution is both expensive and cumbersome.

2. Vary the speed of the compressor. If the compressor is driven by an internal combustion (gasoline or natural gas) engine, it will be possible to reduce the speed of the compressor as the load is reduced. When the cooling load was 30 tons, the compressor would be running at maximum RPM. As the load reduced, the RPM of the compressor would also reduce. At 15 tons the compressor would be running at half its maximum RPM. This is a very good method of capacity control. The temperature differential of the conditioned space can be maintained within a very close range.

   It is very difficult to vary the speed of a compressor that is being driven by an alternating current motor. Multispeed induction motors with 2, 3, or even 4 speeds are available and can be used. However, they are very expensive, and the speed variations are not gradual but change abruptly from one speed to another. Speed variation of alternating current motors is possible by using a drum controller and a resistor placed in series with the starter. However, this system requires expensive switchgear and is seldom used on motors of less than 100 hp.

3. Vary compressor capacity. In this system, the compressor runs at a constant speed, but its efficiency is reduced as the load reduces.

   There are three basic methods of reducing the compressor capacity.

   - Bypassing part of the discharge gas back into the suction line.
   - Holding the suction valve open during part or all of the stroke on one or more cylinders.
   - Varying the clearance pocket in the top of the cylinder.

Each of these methods will work, but holding the suction valve open is the most efficient and is generally used.

CAPACITY CONTROLS

Cylinder Bypass

This method of capacity control consists of a means of bypassing or returning part of the compressed gas in the cylinder to the low side. This bypass arrangement has the effect of reducing the length of the compression stroke so that the volume actually delivered to the discharge line is less than rated capacity. A schematic of a simple cylinder unloader is illustrated in Figure 23.

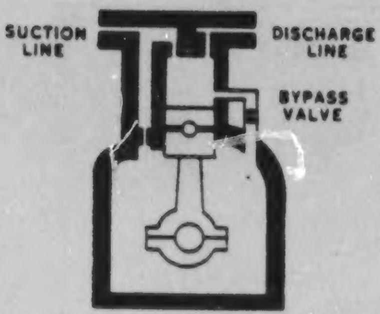

SUCTION LINE
DISCHARGE LINE
BYPASS VALVE

Figure 23. Simple Bypass System

During maximum load, the bypass valve is closed and the complete cylinder is utilized. When the load reduces, the bypass valve is opened; and the vapor goes through the bypass line until the piston moves up the cylinder and closes the bypass port. When the bypass valve is open, only the top half of the cylinder is being used, and the piston is delivering only one-half its rated capacity.

An automatic bypass system is illustrated in Figure 24. During maximum load operation, a piston type valve is held against the bypass port by discharge pressure. When the suction pressure reduces to a predetermined point, the pressure control closes a switch in the electrical control circuit. The completed electrical circuit opens the control solenoid valve in the head pressure line. The pressure behind the piston passes through the bleed line and returns to the low side. The pressure in the cylinder forces the piston off its seat, and part of the vapor in the cylinder is bypassed to the suction manifold.

There are several different types of bypass systems. Some are actuated by suction pressure; others are actuated by the temperature of the conditioned space.

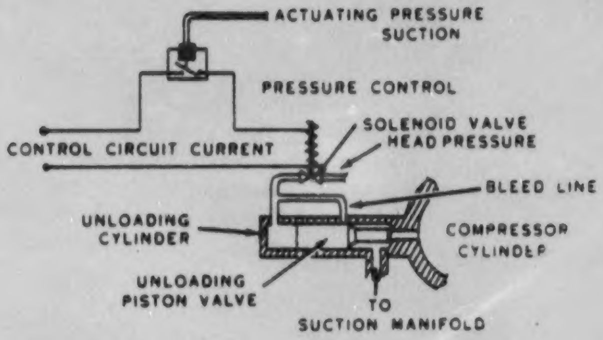

ACTUATING PRESSURE SUCTION
PRESSURE CONTROL
SOLENOID VALVE
HEAD PRESSURE
CONTROL CIRCUIT CURRENT
BLEED LINE
UNLOADING CYLINDER
COMPRESSOR CYLINDER
UNLOADING PISTON VALVE
TO SUCTION MANIFOLD

Figure 24. Automatic Bypass System

Clearance Pocket

The clearance volume (mechanical clearance) is that space between the top of the cylinder and the top of the piston when the piston is at top dead center. The smaller this space, the more efficient the compressor. If it were possible to increase or decrease this space, it would be possible to control the efficiency of the compressor. A simple clearance pocket capacity controller is illustrated in Figure 25.

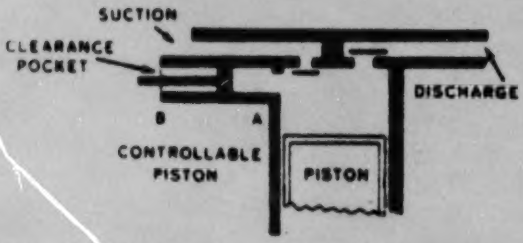


Figure 25. Simple Clearance Pocket Compressor Capacity

Under a maximum load condition the controllable piston is at point A. The compressor is operating at its maximum capacity because the clearance volume is small. As the load decreases, the controllable piston moves toward point B. This movement increases the size of the clearance volume. As the clearance volume increases, the efficiency of the compressor decreases. Compressors equipped with clearance pocket controllers have a tendency to overheat. Therefore, some means of auxiliary cooling (extra cooling fins on the head or a cooling water jacket) must be provided.

The controllable piston can be adjusted manually; however, for smooth efficient operation, it is usually adjusted automatically in response to changes in the low side pressure.

Cylinder Unloaders

This method of compressor capacity control is used almost universally on large multiple cylinder compressors driven by alternating current electrical motors. A device installed in the compressor holds the suction valve of each cylinder open as the load decreases. Assume that a theater with a 30-ton load is being cooled with a four-cylinder compressor. When the unit starts, there is only one cylinder operating. Assume the theater is cool. The other three cylinders have their suction valves automatically held open. As people come into the theater, the air-conditioning load increases, and number two cylinder is automatically brought into operation. The same thing happens for cylinders three, and four, until maximum load is reached. After the sun goes down, the heat load decreases. Number four cylinder is then automatically unloaded by holding the suction valve open again. The same thing happend for cylinders three and two. As the need for refrigeration continues to reduce, number one cylinder reduces thelow side pressure to a predetermined point, and the unit turns off. With this system, there is very little on-off operation. The compressor runs continuously and is producing refrigeration in varying amounts as required. A system of this type will maintain very close temperature control.

A typical cylinder unloader mechanism consists of four main units: unloader sleeve, unloader power element, hydraulic relay, and capacity control valve.

OPERATION. The operation can be traced in Figure 26. The pressure from the crankcase is fed through a surge chamber which changes the pulsating pressure to a stabilized oil flow to the capacity control valve (1). As the increase of pressure enters the valve, an internal bellows is expanded; and the push rods attached to the needle and seat assembly pull the needle toward the seat. This action increases the control oil pressure. The increase of pressure in the crankcase is also passed through the oil pump to the hydraulic relay (2). NOTE: This pressure is true oil pressure plus suction pressure. The increased oil pressure will bleed through the port in the end of the relay piston and force the piston to move one notch against the ball and spring assembly for each increase of 2 psi. For each increase of 2 psi, the repositioning opens a port leading to an unloader power element (3). NOTE: There is one less cylinder unloader power element than total number of cylinders; this means that one cylinder will be fully loaded at all times.

As the unloader power element (3) has the increased power applied, it is forced against the piston face, opposing the spring pressure and pushing up on the lifting fork assembly (4). The fulcrum action causes the lifting fork to drop, which allows the unloader sleeve (5) to drop. The dropping action of the unloader sleeve allows the push pins (6) to fall against the face of the unloader sleeve allowing the suction disc (7) to seat on top of the cylinder and load the cylinder.

As the pressure decreases in the crankcase, the decrease through the capacity control valve (1), causes the bellows to contract and the push pins (9) push the needle away from the seat, decreasing the control oil pressure (10). This decreased control oil pressure will allow the spring pressure to reposition the piston, closing off feedline ports to the unloader power elements one notch against the ball and seat assembly (11) for each 2 to 2.5 psi change in pressure. As the pressure is no longer being applied to the unloader power element (3), the internal spring pressure forces the excessive oil to return by gravity feed to the crankcase. The fulcrum action of the lifting fork (4) forces up on the unloader sleeve (5). This lifting action pushes the lifting pin (6) against the disc type suction valve (7) raising it off the seat, unloading the cylinder.

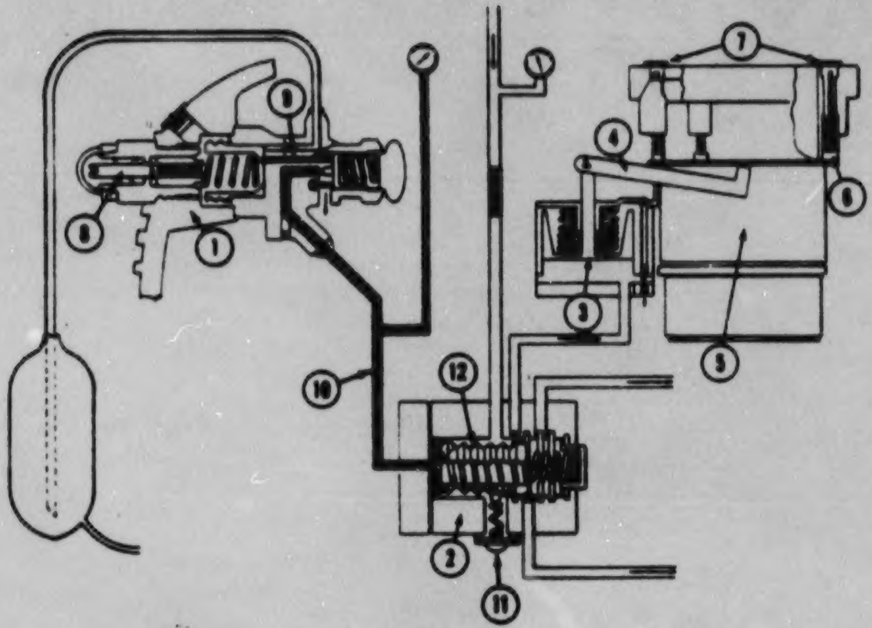


Figure 26. Cylinder Unloader Circuit

ADJUSTMENT. The capacity control mechanism must be adjusted to maintain a balance between the load and compressor capacity. This adjustment is made by turning the external adjustment stem on the capacity control valve. Turning the adjusting stem clockwise (in) unloads the cylinders. Turning the adjusting stem counterclockwise (out) loads the cylinders.

The ideal setting of the capacity control valve is achieved when the first cylinder unloads at a pressure of 3 psi below the design suction pressure. The capacity control valve loads and unloads cylinders in steps to balance the compressor capacity with the heat load. The compressor must be completely loaded before the capacity control valve can be correctly set. If it is impossible to fully load the system before setting the control valve, adjust the valve to give a minimum of cycling and make the final adjustment when the system is fully loaded. A step-by-step procedure for adjusting the capacity control mechanism is contained in the workbook exercises that are used with this study guide.

TROUBLE ANALYSIS

Determining the cause of a malfunction in an air-conditioning system is usually much more difficult than repairing it once the trouble is located. The following is a trouble analysis chart which may be an aid to you in finding possible troubles.

TROUBLE	PROBABLE CAUSE	REMEDY
1. Low suction pressure	Cylinder unloader out of adjustment	Adjust
	Restricted liquid line	Clear restriction
	Insufficient airflow	(1) Clean filter (2) Tighten air hander belt
	T.E.V. power assembly lost charge	Replace T.E.V.
2. High suction pressure	Cylinder unloader out of adjustment	Adjust
	Excessive load on system	Close doors
3. Low discharge pressure	Outside air temperature too low	Consider possibility of capacity for condenser
	Fan pressure switch out of adjustment	Adjust
4. High discharge pressure	Fan pressure switch out of adjustment	Adjust fan switch
	High outside temperature	Check condenser for cleanliness
	Dirty condenser	Clean condenser
	Noncondensables in system	Purge
5. Abnormal Noises	Low compressor oil level	Add oil
	Loose belt	Tighten belt
	Broken motor mounts	Replace mounts
	Vibrating refrigerant lines	Anchor lines
	Bearings on fan or motors bad	Replace bearings or replace complete fan or motor
	Compressor slugging	Install accumulator

QUESTIONS

1. What is a direct expansion type equipment cooling system?

2. Why is it dangerous to get nearer than one foot to a voltage of 5,000 volts?

3. How can controls shock you if the switch is turned off?

4. What is the difference between comfort cooling and equipment cooling?

5. How does a high limit humidity control function?

6. What is the purpose of face and bypass dampers in a system?

7. What is a DX coil?

8. List the methods of capacity control of TEVs and evaporators.

9. Explain how the compressor would stop if PE relay opened. Refer to Figure 9.

10. What safety controls stop the compressor?

11. Why are pneumatic controls not usually used in domestic applications?

12. What are three advantages of pneumatic controls?

13. What are the meanings of main and branch line pressures?

14. What is a reverse acting controller?

15. What is the difference between a pneumatic-electric relay and an electric-pneumatic relay?

16. What are the five steps necessary in adjusting a pneumatic controller?

17. What is the primary medium used to control temperature in equipment cooling systems?

18. What two things must be known to calculate coil capacity?

19. How is the efficiency of a coil determined?

20. What is a 100 percent efficient coil?

21. Explain the operation of the hot gas bypass system.

22. Explain the operation of the adjustable clearance pocket.

23. What is the purpose of cylinder unloaders?

24. Explain the principle of operation of cylinder unloaders.

25. Explain the procedure for adjusting cylinder unloaders.

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WORKBOOKS

3ABR54530-VIII-5-P1 thru 7-P10

Technical Training

Refrigeration and Air-Conditioning Specialist

HEAT PUMPS, PACKAGE AIR CONDITIONER, AND DIRECT EXPANSION AIR-CONDITIONING SYSTEMS

October 1975

USAF SCHOOL OF APPLIED AEROSPACE SCIENCES
Department of Civil Engineering Training
Sheppard Air Force Base, Texas

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Sheppard AFB, Texas

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October 1975

FAMILIARIZATION OF HEAT PUMPS

OBJECTIVE: Using heat pump and reversing valve demonstrator correctly identify components and trace the flow of refrigerant through the cooling and heating cycles.

1. List and explain the three sources of heat for the heat pump.

a. ____________________

____

b. ____________________

____

c. ____________________

____

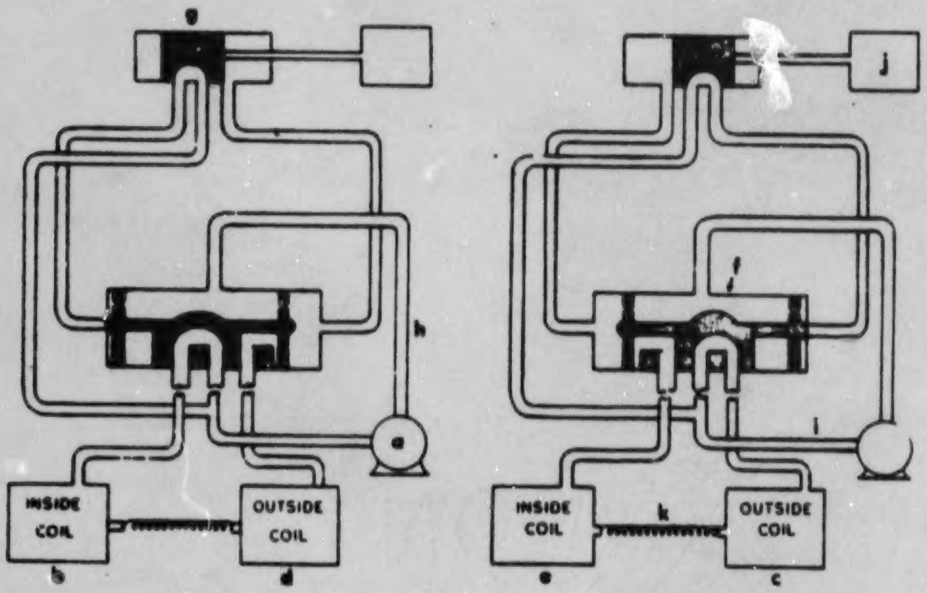
g
a
h
INSIDE COIL
OUTSIDE COIL
b
d
j
f
i
k
INSIDE COIL
OUTSIDE COIL
e
c

Figure 1. Heat Pump Components

2. Match the letters on the above diagrams with the proper name of that component.

____Compressor

____Reversing Valve

____Metering Valve

____Suction Line

____Evaporator (Cooling)

____Evaporator (Heating)

____Condenser (Cooling)

____Condenser (Heating)

____Pilot Valve

____Solenoid

____Discharge Line

3. Trace the flow of refrigerant through the heat pump diagrams shown below, indicate direction of flow.

   a. Cooling cycle.

   b. Heating cycle.

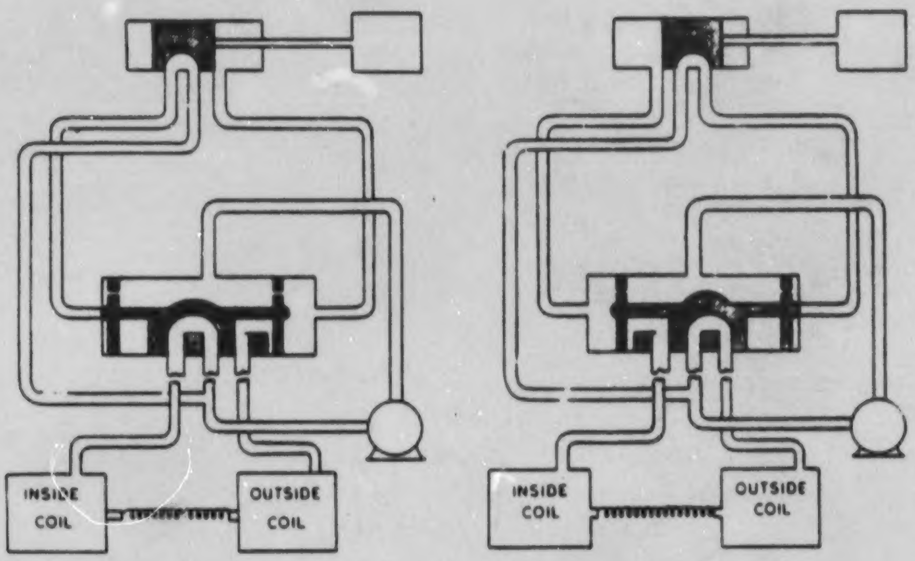

Figure 2. Heat Pump Cycles

4. What are the two main operational problems with heat pumps?________________

____

5. What system pressure moves piston in reversing valve?________________

____

6. What device controls the positioning of the reversing valve piston?

____

7. Is the solenoid coil energized on the heating or cooling cycle? ____________

____

8. Does the refrigerant flow through the compressor reverse during the reverse cycle operation? ____________________________

Checked by ____________________
Instructor

WB 3ABR54530-VIII-6-P1

FAMILIARIZATION OF THE PACKAGE AIR CONDITIONER

OBJECTIVE: Using the package air conditioner, trace the flow of water and air, correctly identify the components, perform preoperational check and operate system as required by instructor.

PART I

NOTE: Turn power OFF.

1. Remove the cover of the package unit.
2. Locate, identify and list function of components.

NUMBER	COMPONENT	FUNCTION
1.		
2.		
3.		
4.		
5.		
6.		
7.		
8.		

NUMBER	COMPONENT	FUNCTION
9.	____________	____________
		____________
10.	____________	____________
		____________

PART 2

NOTE: Turn power OFF.

Instructor will determine whether this exercise is to be performed individually or by groups.

1. Start at the water-regulating valve and trace the flow of the condensing water through the system.

2. Start at the compressor and trace the flow of refrigerant through the system.

3. Start at the filter and trace the flow of air through the system.

4. Is the water regulating valve located at the inlet or outlet of the condenser?

   ____

5. Does the water flow through the shell or through the tubing? ____________

   ____

6. What type refrigerant does the package air conditioner use? ____________

   ____

7. Does the refrigerant flow through the evaporator through a single or multiple circuit? ____

8. Where does the return air enter the package air conditioner? ____________

   ____

9. Is the air forced or drawn through the evaporator? ____________

   ____

Checked by ______________________
Instructor

PART 3

1. Perform preoperational checks.
   - a. Power in OFF position.
   - b. Remove cover.
   - c. Check evaporator fan for freedom of movement.
   - d. Check belt for proper tension and alignment.
   - e. Check components for visual damage and security of mounting.
   - f. Inspect filter for cleanliness.
   - g. Check evaporator for air blockage.
   - h. Check availability of water for condenser.
   - i. Replace cover.
2. Operate unit.
   - a. Turn ON condenser water approximately twenty (20) seconds before power is applied.
   - b. Turn selector switch to OFF.
   - c. Close circuit breaker switch.
   - d. Turn selector switch to FAN.

     NOTE: Check for proper air flow.
   - e. Adjust thermostat to desired setting.
   - f. Turn selector switch to COOL.

     NOTE: Compressor may not come on due to thermostat being set above ambient temperature.
   - g. Determine supply air temperature __________________ degrees.
   - h. Determine return air temperature __________________ degrees.

     NOTE: A 20-degree temperature split indicates proper cooling; a greater temperature split indicates low air flow.

3. Accomplish shutdown procedures.

   a. Selector switch in the OFF position.

   b. Breaker switch in the OFF position.

   c. Turn condenser water OFF.

MAJOR COMPONENTS

OBJECTIVE: To locate, identify, and state the functions of the major components of the 25-ton system.

NOTE: Your instructor will tour the 25-ton trainer with you and explain its operation. From this tour you will learn about the following components:

MAJOR COMPONENTS	FUNCTIONS
1. Compressor	1. ____________________ ____________________
2. Air Handler	2. ____________________ ____________________
3. Face and Bypass Dampers	3. ____________________ ____________________
4. TEV Bank and Evaporator	4. ____________________ ____________________
5. Test Cabinet	5. ____________________ ____________________
6. Condenser Systems	6. ____________________ ____________________
7. Boiler	7. ____________________ ____________________
8. Hot Water Converter	8. ____________________ ____________________
9. Reheat Coils	9. ____________________ ____________________
10. Load Coils	10. ____________________ ____________________

MAJOR COMPONENTS	FUNCTIONS
11. Condensate Return System	11. ______________________ ______________________
12. Air Compressor	12. ______________________ ______________________

Checked by______________________
Instructor

515

COMPRESSOR ELECTRICAL CONTROL CIRCUITS

OBJECTIVE: Using the 25-ton trainer, locate, identify, state their function, and wire safety control circuits of the 25-ton system.

PART 1

NOTE: The safety devices in the control circuits are designed to shut the compressor down directly or after a short pump-down period.

DIRECT SHUTDOWN SAFETY DEVICES

1. High-pressure motor control
2. Low-pressure motor control
3. Oil safety switch

PUMP-DOWN SAFETY DEVICES

1. Fan - interlock contacts
2. Freeze protection thermostat

NOTE: A manual solenoid switch (S-2) on the control panel is also in the safety circuit that causes pump-down; this switch is not an automatic safety device, but can be used as a manual pump-down control.

1. What is meant by direct shutdown? ________________________________

____

2. What is a pump-down cycle? ________________________________

____

3. What is the function of the oil safety switch? ________________________________

____

4. What does the term "control circuit" mean as in a line starter? ________________

____

5. What safety devices deenergize the line-starter holding coil? ________________

____

PART 2

PROCEDURE

1. Use a red pencil and connect the units in figure 3 of the control circuit in series.

2. Use a blue pencil and connect the units in figure 3 of the pressure operated circuit in series.

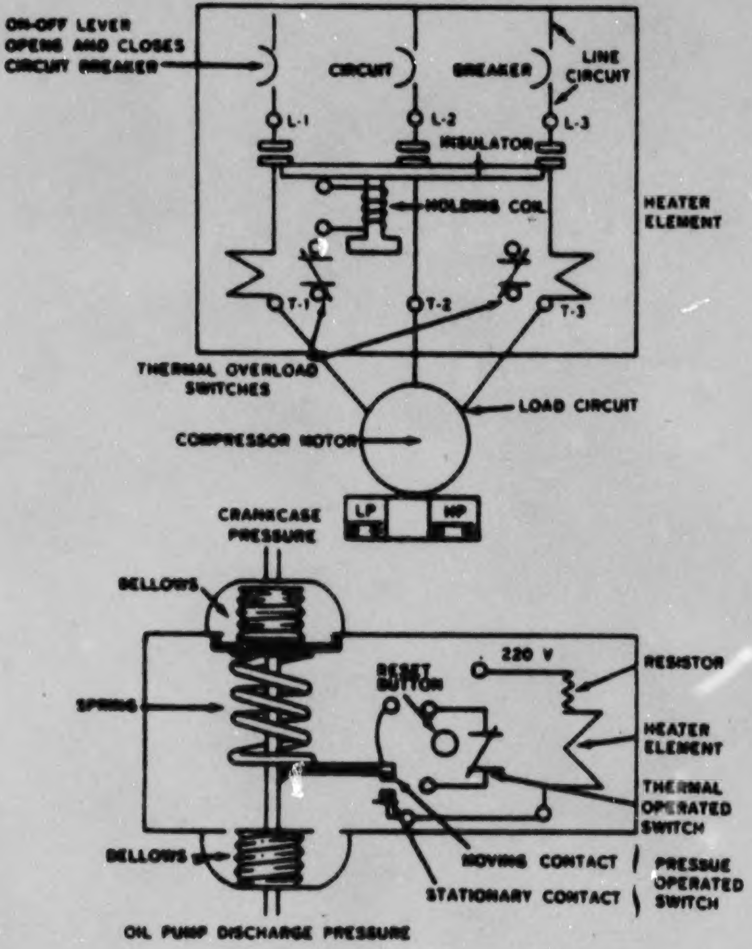
ON-OFF LEVER
OPENS AND CLOSES
CIRCUIT BREAKER
CIRCUIT
BREAKER
LINE
CIRCUIT
L-1
L-2
L-3
INSULATOR
HOLDING COIL
HEATER
ELEMENT
T-1
T-2
T-3
THERMAL OVERLOAD
SWITCHES
LOAD CIRCUIT
COMPRESSOR MOTOR
LP
HP
CRANKCASE
PRESSURE
BELLOWS
SPRING
220 V
RESISTOR
RESET
BUTTON
HEATER
ELEMENT
THERMAL
OPERATED
SWITCH
BELLOWS
MOVING CONTACT
STATIONARY CONTACT
PRESSUE
OPERATED
SWITCH
OIL PUMP DISCHARGE PRESSURE

Figure 3. Control Circuit and Pressure Operated Circuit

3. Use a blue pencil and connect the safety controls (figure 4) in series:

   a. Will the fan stop when you open S-2? __________

   b. Will the fan stop when you open R-1? __________

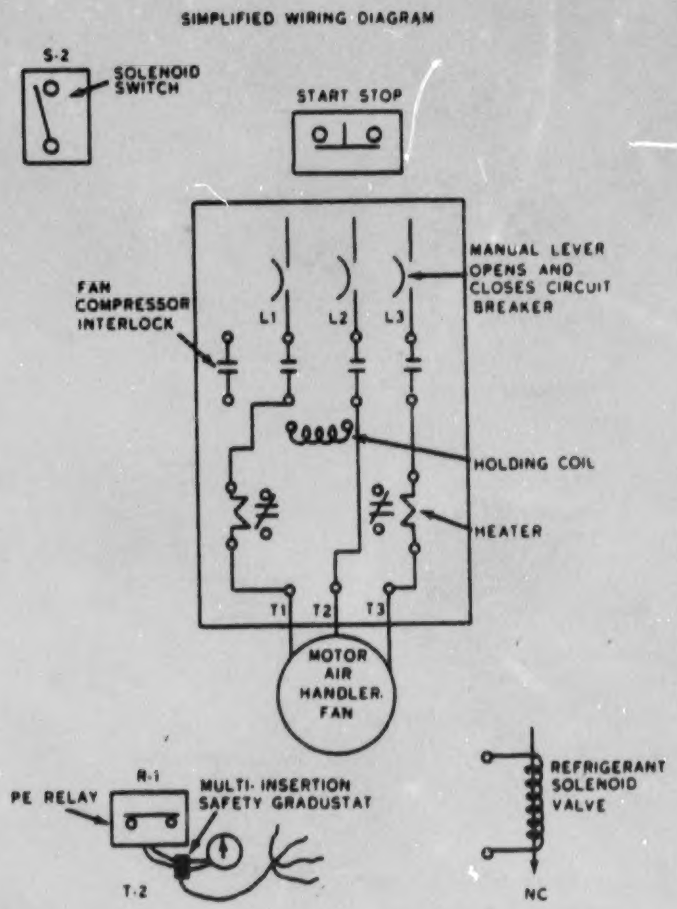
SIMPLIFIED WIRING DIAGRAM
S-2
SOLENOID SWITCH
START STOP
MANUAL LEVER OPENS AND CLOSES CIRCUIT BREAKER
FAN COMPRESSOR INTERLOCK
L1
L2
L3
HOLDING COIL
HEATER
T1
T2
T3
MOTOR AIR HANDLER FAN
R-1
PE RELAY
MULTI-INSERTION SAFETY GRADUSTAT
T-2
REFRIGERANT SOLENOID VALVE
NC

Figure 4. Magnetic Line Starter and Air Handler Controls

4. You have connected the compressor motor magnetic starter, the air handler fan motor starter and the safety controls in previous projects. Without referring to the projects, connect the complete system in the diagram (figure 5) as follows:

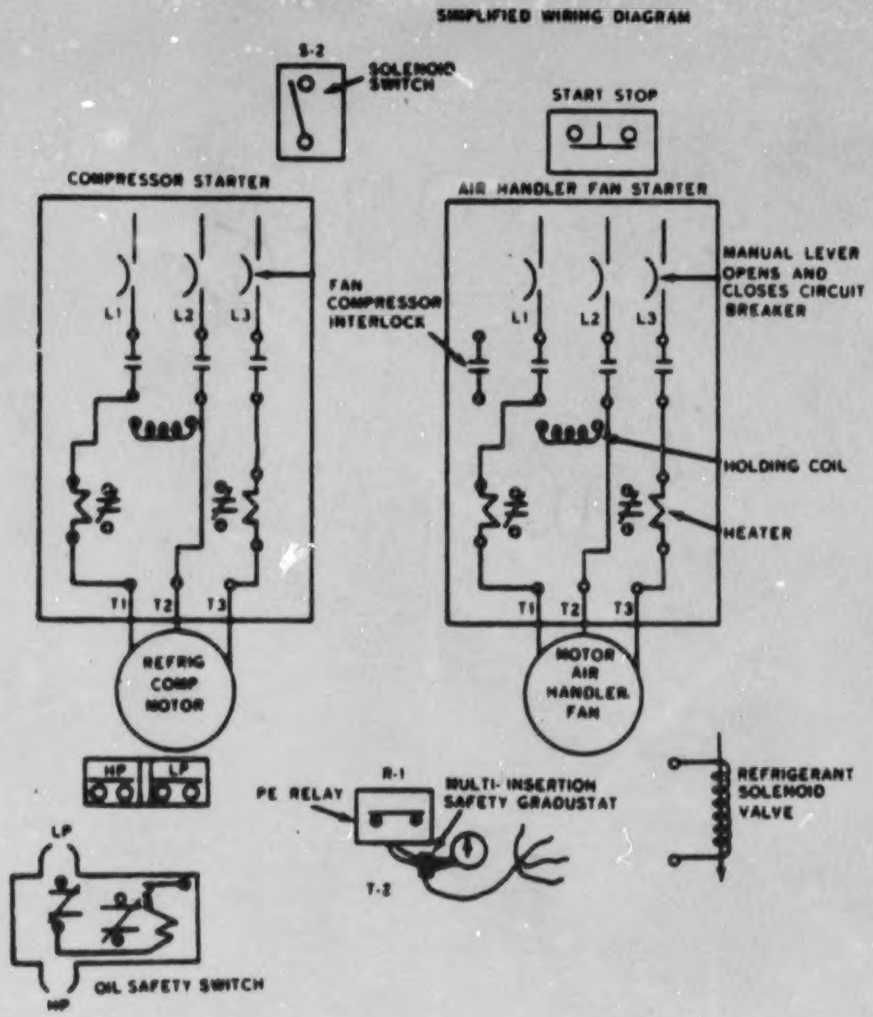
SIMPLIFIED WIRING DIAGRAM
S-2
SOLENOID SWITCH
START STOP
COMPRESSOR STARTER
AIR HANDLER FAN STARTER
FAN COMPRESSOR INTERLOCK
MANUAL LEVER OPENS AND CLOSES CIRCUIT BREAKER
L1
L2
L3
HOLDING COIL
HEATER
T1
T2
T3
REFRIG COMP MOTOR
MOTOR AIR HANDLER FAN
HP
LP
R-1
PE RELAY
MULTI- INSERTION SAFETY GRADUSTAT
T-2
REFRIGERANT SOLENOID VALVE
LP
OIL SAFETY SWITCH
HP

Figure 5. Compressor and Air Handler Controls

5. Have the instructor check your work on the preceding page. Any corrections should be corrected on the drawing below.

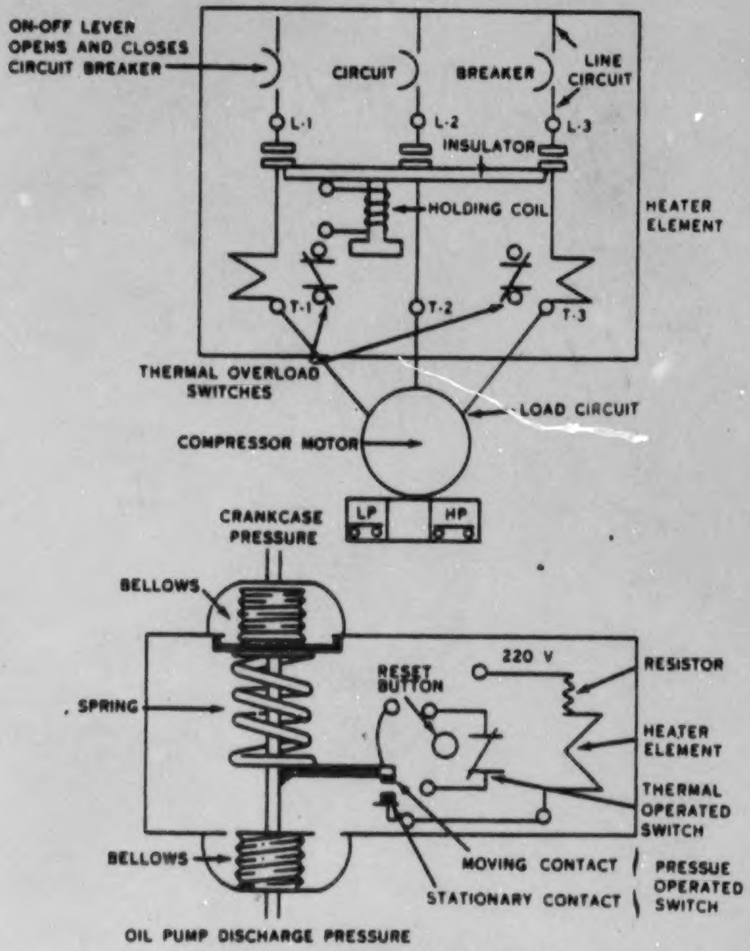
ON-OFF LEVER OPENS AND CLOSES CIRCUIT BREAKER
CIRCUIT
BREAKER
LINE CIRCUIT
L-1
L-2
L-3
INSULATOR
HOLDING COIL
HEATER ELEMENT
T-1
T-2
T-3
THERMAL OVERLOAD SWITCHES
LOAD CIRCUIT
COMPRESSOR MOTOR
LP
HP
CRANKCASE PRESSURE
BELLOWS
220 V
RESET BUTTON
RESISTOR
SPRING
HEATER ELEMENT
THERMAL OPERATED SWITCH
BELLOWS
MOVING CONTACT
STATIONARY CONTACT
PRESSUE OPERATED SWITCH
OIL PUMP DISCHARGE PRESSURE

Figure 6. Control Circuitry

Checked by________________________
Instructor

COMPLETE TEMPERATURE AND HUMIDITY CONTROL CIRCUITS

OBJECTIVE: Using the 25-ton trainer, locate series 90 operational and capacity controls, complete wiring schematic and adjust for proper operation.

PART 1

INSTRUCTIONS: Using the diagram in figure 7, schematically wire the humidity control circuit.

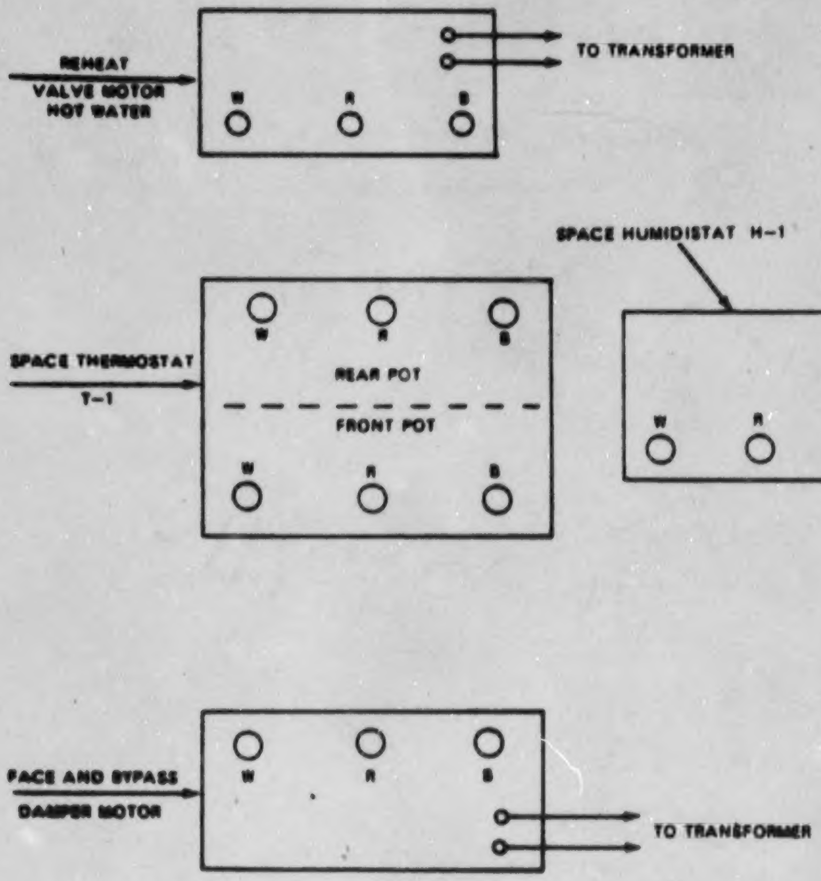
TO TRANSFORMER
REHEAT
VALVE MOTOR
HOT WATER
W
R
B
SPACE HUMIDISTAT H-1
W
R
B
SPACE THERMOSTAT
T-1
REAR POT
FRONT POT
W
R
B
W
R
B
W
R
B
FACE AND BYPASS
DAMPER MOTOR
TO TRANSFORMER

Figure 7. Complete Temperature and High Limit Humidity Control

Checked by ______________________
Instructor

PART 2

ADJUSTMENT OF PRESSURE SWITCH P-1

NOTE: Place pressure switch P-1 in control of the three-way water-cooled condenser valve.

1. Place throttling range to minimum.
2. Center three-way valve using setscrew on P-1 (wiper also centered).
3. Observe the head pressure. ____________________psi.
4. Adjust scale plate to the observed head pressure.
5. Set P-1 to desired pressure (100 psi) and throttling range to C.

OPERATE FACE AND BYPASS DAMPER

1. Set thermostat T-1 to 75°F.
2. Set high limit humidistat H-1 to 50 percent.
3. Place a 10-ton hot water load on system.
4. Wait ten minutes for system to stabilize, then observe system.
    a. Room temperature____________________
    b. Room percent humidity________________percent
    c. Position of face damper_______________
    d. Position of reheat valve_______________
5. Add steam to room and observe conditions of 4a, b, c, and d.

Checked by ____________________________
Instructor

EQUIPMENT COOLING PNEUMATIC CONTROLS

OBJECTIVE: Using the 25-ton trainer, locate pneumatic operational and capacity controls, state their functions, connect components in proper sequence and adjust for proper operation.

PNEUMATIC ROOM HUMIDISTAT (H-2)

1. Locate the units shown in figure 7 on the trainer.
2. With a red pencil, connect the items in figure 7 as they are connected on the 25-ton trainer.

PNEUMATIC FREEZE PROTECTION THERMOSTAT

1. Locate the units shown in figure 8 on the trainer.
2. In figure 8 connect the pneumatic lines with a red pencil.
3. In figure 8 connect the electrical lines with a blue pencil.
4. On the trainer, set thermostat T-2 to 50°F.
5. Adjust relay R-1 "cut-in" to 10 psi and differential to 2 psi.
6. Start the 25-ton system and observe T-2 gage pressure. __________psi

   NOTE: When air leaving cooling coil decreases below 50°F, compressor will pump down and stop.
7. With unit stopped, what is T-2 gage pressure? ____________psi
8. Adjust T-2 to 40°F (compressor should start).

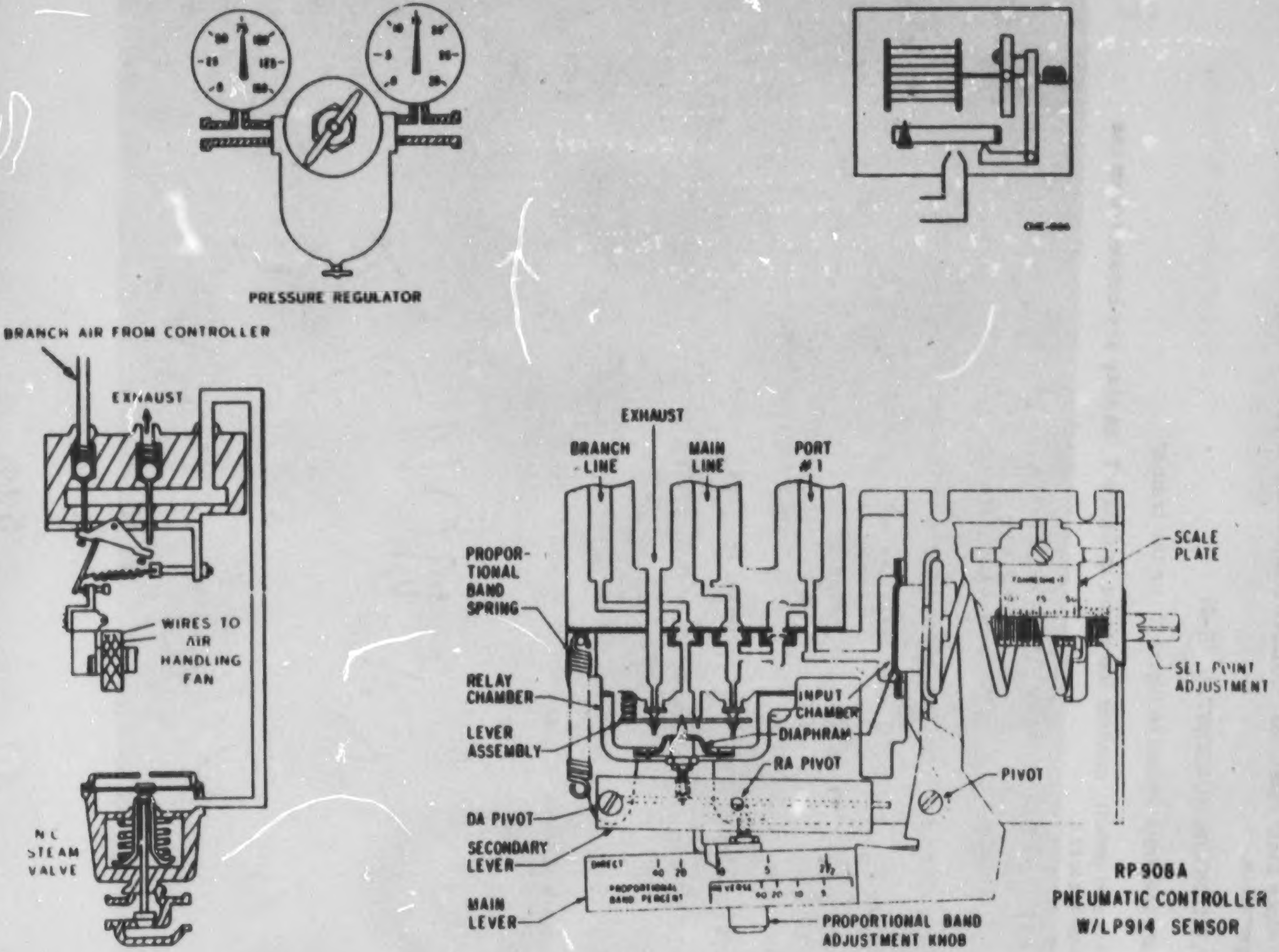
PRESSURE REGULATOR
BRANCH AIR FROM CONTROLLER
EXHAUST
WIRES TO AIR HANDLING FAN
N.C. STEAM VALVE
EXHAUST
BRANCH LINE
MAIN LINE
PORT #1
PROPORTIONAL BAND SPRING
RELAY CHAMBER
LEVER ASSEMBLY
DA PIVOT
SECONDARY LEVER
MAIN LEVER
INPUT CHAMBER
DIAPHRAM
RA PIVOT
PIVOT
SCALE PLATE
SET POINT ADJUSTMENT
DIRECT 60 20 10 5 2½
PROPORTIONAL BAND PERCENT
REVERSE 60 20 10 5
PROPORTIONAL BAND ADJUSTMENT KNOB
RP 908A PNEUMATIC CONTROLLER W/LP914 SENSOR

Figure 7. Low Limit Humidification System

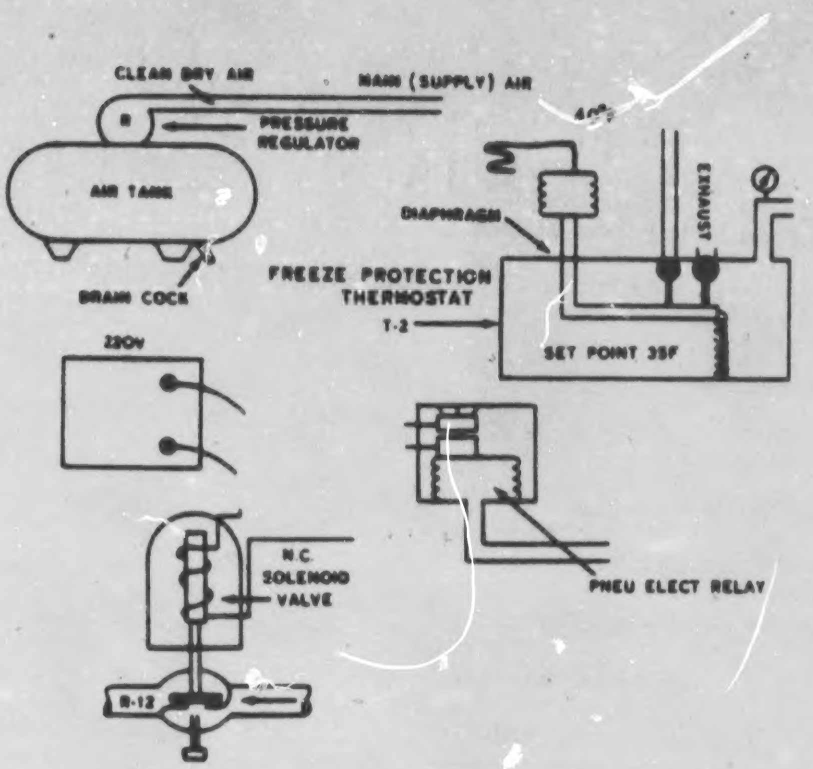
CLEAN DRY AIR
MAIN (SUPPLY) AIR
R
PRESSURE REGULATOR
AIR TANK
DRAIN COCK
40°F
EXHAUST
DIAPHRAGM
FREEZE PROTECTION THERMOSTAT
T-2
SET POINT 35F
220V
N.C. SOLENOID VALVE
PNEU ELECT RELAY
R-12

Figure 8. Freeze Protection System

9. Briefly explain the operations of the freeze protection thermostat and pneumatic-electric relay R-1.

____

____

____

____

Checked by______________________
Instructor

IDENTIFICATION AND ADJUSTMENT OF CYLINDER UNLOADERS

OBJECTIVE: Using the 25-ton trainer, locate compressor capacity control, state functions and adjust for proper operation.

PART 1

1. Identify the numbered items in figure 9 by placing their identifying numbers in the spaces below their names.

NO.	NAME	PURPOSE
	Hydraulic Relay	
	Hydraulic Relay Piston	
	Ball and Spring Assembly	
	External Adjusting Stem	
	Push Pins	
	Control Oil Pressure Line	
	Capacity Control Valve	
	Unloader Power Element	
	Lifting Fork	
	Lifter Spring and Pins	
	Suction Valve	
	Unloader Sleeve	

2. In the space immediately following the item's name, briefly describe its purpose.

3. In figure 9, color the oil pump pressure, suction pressure, and control oil pressure according to the following code:

a. Oil pump pressure - Red

b. Suction pressure - Green

c. Control oil pressure - Black

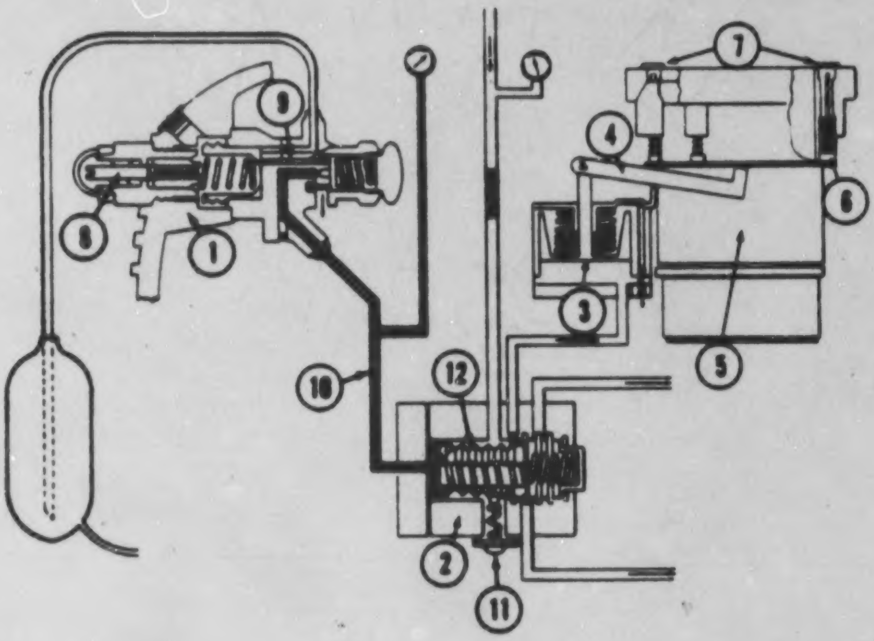

Figure 9. Cylinder Unloader

Checked by________________________
Instructor

PART 2

OBJECTIVE: To learn to adjust cylinder unloaders.

NOTE: This project will be performed as a team effort.

1. Operate the 25-ton system as follows:
   a. Connect an ammeter to one compressor load wire in the compressor starter box.
   b. Start the compressor.
   c. Place a 25 gpm hot water load on the system.
   d. Wait five minutes for the system to stabilize.
2. Operate the compressor capacity control by turning the cylinder unloader external adjusting stem counterclockwise until all the cylinders are loaded and record the following:
   a. Compressor Motor Amperes ____________________
   b. Suction Pressure ____________________
   c. Oil Pump Pressure ____________________
   d. Control Oil Pressure ____________________
   e. Evaporator Temperature ____________________
3. Check performance of the cylinder unloader as follows:
   a. Turn the cylinder unloader adjusting stem clockwise until one cylinder unloads and record the following:
      (1) Compressor Motor Amps ____________________
      (2) Suction Pressure ____________________

NOTE: This is the control point. The last unloading step will cut out when the suction pressure drops five pounds below this point. The last loading step will cut in two pounds above this control point.

      (3) Oil Pump Pressure ____________________
      (4) Control Oil Pressure ____________________
      (5) Evaporator Temperature ____________________

b. Turn the unloader external adjusting stem clockwise until another cylinder unloads.

The compressor motor is now using how many amperes? ____________

c. Turn adjusting stem clockwise until the compressor is completely unloaded. (Do not force stem.)

d. Explain how you may determine the number of cylinders that are loaded by observing:

(1) Oil Pressure Gages ____

____

____

____

____

____

(2) Ammeter readings ____

____

____

____

____

____

4. Field method of cylinder unloader adjustment

a. This simple method of adjustment is accomplished in four easy steps as follows:

(1) Place a normal operating load on the system.

(2) Fully load the compressor by turning the adjusting stem full counter-clockwise (all cylinders will be loaded).

(3) Let unit run until the evaporator temperature decreases to the desired temperature.

(4) Turn the adjusting stem clockwise slowly until the first cylinder unloads.

5. Manufacturer's method of cylinder unloader adjustment

   a. A variation of seven pounds in suction pressure is required to operate the unloaders from fully unloaded to full loaded positions in compressors using R-12. In compressors using R-22, an eleven pound variation in suction pressure is required. Seven and eleven pound capacity control valve springs are available and must be used in conjunction with corresponding refrigerants in order to obtain proper unloader operation. If, with a given suction pressure, the external adjusting stem is turned in until the first cylinder unloads (known as the control point) the last unloading step will cut out when the suction pressure drops five pounds below this point. The last unloading step will cut in two pounds above this control point.

      (1) Determine the saturation pressure corresponding to the minimum desired evaporator temperature. This information will be provided by the instructor.

      (2) Determine the control point by adding 5 psi for R-12 (8 psi for R-22) to the saturation pressure.

      (3) With the adjusting stem all the way out, operate the system under the full load conditions to obtain a suction pressure higher than that of the control point.

      (4) Reduce crankcase pressure to the control point by slowly front seating the suction service valve.

      (5) Turn the control valve adjusting stem in slowly (clockwise) until the first cylinder unloads. (One full turn of the valve stem changes the unloading point 6 pounds.)

      (6) Recheck by opening suction shutoff and then slowly closing. Observe suction pressure gage and listen for the first cylinder to unload when suction pressure reaches the control point.

      (7) Open suction shutoff valve.

Checked by______________________
Instructor

PREOPERATIONAL CHECK OF THE 25-TON TRAINER

OBJECTIVE: Using the 25-ton trainer and given procedures, perform a preoperational check on the system.

CAUTIONS: Do not operate any untagged valves without the instructor's approval. Observe all safety precautions.

PREOPERATIONAL CHECKS

NOTE: Preoperational checks are made with the power off to protect you.

1. Make sure all the power switches are OFF at the control panel.

2. Check the condensing systems for visual damage, valve positions, and refrigerant level in the receivers.

   a. Refrigerant level ______________________________

   b. Visual damage to the system ____

   ____

   ____

   ____

   c. Valve positions

   NOTE: Refer to the refrigerant piping diagram when checking valve positions (figure 10).

   (1) Close all condenser inlet valves except on the condenser being used.

   (2) Close all receiver inlet valves except on the condensing system being used.

   (3) Close all receiver outlet valves except on the system being used.

   NOTE: All valves on the system to be used must be wide open for operation.

CAUTION: Do not operate any untagged valves on the trainer; doing so may result in damage to the system.

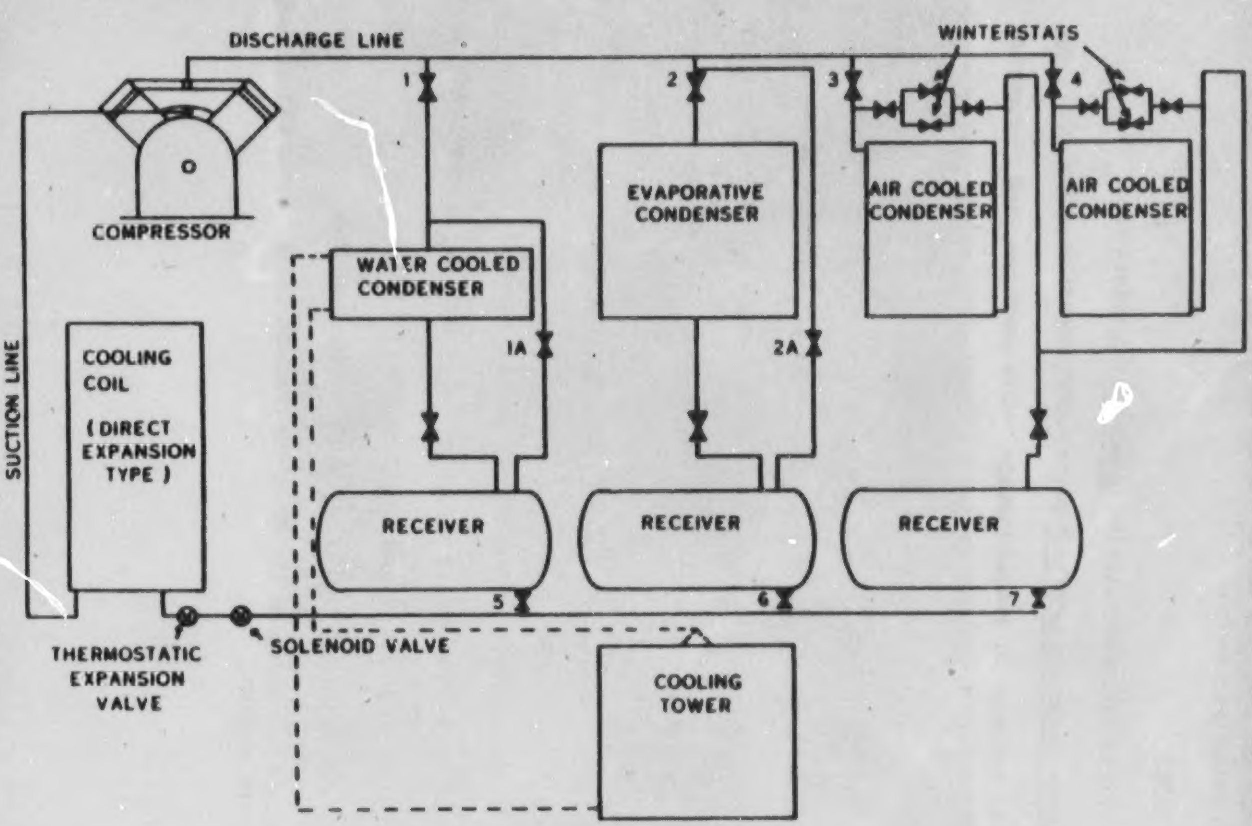
DISCHARGE LINE
WINTERSTATS
1
2
3
4
COMPRESSOR
WATER COOLED CONDENSER
EVAPORATIVE CONDENSER
AIR COOLED CONDENSER
AIR COOLED CONDENSER
SUCTION LINE
COOLING COIL (DIRECT EXPANSION TYPE)
1A
2A
RECEIVER
RECEIVER
RECEIVER
5
6
7
THERMOSTATIC EXPANSION VALVE
SOLENOID VALVE
COOLING TOWER

Figure 10. Refrigerant Piping Diagram

3. Check compressor service valves (should be in gage position).

4. Check compressor oil level:

   NOTE: Oil level should be 1/4 to 3/4 in sight glass.

   a. Oil level______________________

   b. Oil sometimes remains in suction line traps and will not return until system has reached full load operation.

   NOTE: Check oil level again during operation.

5. Check compressor belts for tension (matched set tension should be the same on all).

6. Check manual valves on TEV bank. (Following valves must be open: A, B, D, E, and F.)

   NOTE: All other valves must be closed.

7. Check steam valve to hot water converter to make sure it is OPEN.

8. Open hot water valve to load coil to 1/2 turn. (Adjust to 10 GPM after startup.)

9. Check boiler for proper water level and pilot flame.

10. Check air compressor for belt tension and oil level.

11. Drain condensate from air compressor receiver tank.

12. Turn on the four small red tipped circuit breakers on the control panel.

    a. Steam boiler.

    b. Central transformer.

    c. Air compressor.

    d. Condensate return pump.

    NOTE: These units must be operating properly before main until will operate.

Checked by______________________________
Instructor

OPERATION OF THE 25-TON TRAINER

OBJECTIVE: Using 25-ton trainer and prescribed procedures set up and operate 25-ton system using condenser selected by instructor.

NOTE: The instructor will select one of the three condenser systems for performing this project.

OPERATING WITH AIR-COOLED CONDENSERS

Preoperational Check:

1. Turn all switches OFF at control panel.
2. Check refrigerant level at air-cooled condenser receiver (75 percent full).

   The refrigerant is at the ______________________________ level.
3. Open valves 3, 4, and 7; close valves 1, 1A, 2, 2A, 5, and 6.
4. Check compressor oil level (1/4 to 3/4 on sight glass).

   Compressor oil level is at ____.
5. Check expansion valves.
6. Open steam valve to hot water converter.
7. Open hot water load valve, 1/2 turn.
8. Close (ON) four small red-tipped switches on control panel.

Starting Procedures:

1.	Air-cooled condenser #1	(ON)
2.	Air-cooled condenser #2	(ON)
3.	Hot water rheostat	(NORMAL)
4.	Hot water pump	(ON)
5.	Air handling unit	(ON)
6.	Refrigeration compressor	(ON)
7.	Liquidline solenoid S-2	(ON)

Operating Procedures:

1. Observe suction and discharge pressures.
   - a. If discharge pressure exceeds 175 psig, prepare to turn off liquid solenoid switch S-2. Discharge pressure is ______________________________.
   - b. If the compressor stops automatically on high head pressure (175 psig), turn off solenoid switch S-2 immediately.
2. Adjust water load valve to 10 GPM.
3. Observe temperature, pressure, and oil gages.

Stopping Procedures:

1.	Liquidline solenoid S-2 (wait for pump down)	(OFF)
2.	Refrigeration compressor	(OFF)
3.	Air handling unit	(OFF)
4.	Hot water pump	(OFF)
5.	Hot water reheostat	(LOW)
6.	Air-cooled condenser #2	(OFF)
7.	Air-cooled condenser #1	(OFF)

OPERATING WITH EVAPORATIVE CONDENSER

Preoperational Check:

1. Turn all switches OFF at control panel.
2. Check refrigerant level at evaporative condenser receiver (75 percent full).
3. Open valves 2, 2A, and 6; close valves 1, 1A, 3, 4, 5, and 7.
4. Check compressor oil level (1/4 to 3/4 on sight glass).
5. Check expansion valves.
6. Open steam valve to hot water converter.
7. Open hot water load valve 1/2 turn.
8. Close (ON) five small red-tipped switches on control panel.

Starting the System:

1.	Evaporative condenser pump	(ON)
2.	Evaporative condenser fan	(ON)
3.	Selector switch S-6 (for damper)	(UP)
4.	Hot water rheostat	(NORMAL)
5.	Hot water pump	(ON)
6.	Air handling unit	(ON)
7.	Refrigeration compressor	(ON)
8.	Liquidline solenoid S-2	(ON)

Operating the System:

1. Observe suction and discharge pressures.
    a. If discharge pressure exceeds 145 psig, prepare to turn off liquid solenoid switch S-2.
    b. If the compressor stops automatically on high head pressure, turn off liquid solenoid switch S-2.
2. Adjust water load valve to 10 GPM.
3. Observe temperature, pressure, and oil gages.

Stopping the System:

1.	Liquidline solenoid (wait for pump down)	(OFF)
2.	Refrigeration compressor	(OFF)
3.	Air handling unit	(OFF)
4.	Hot water pump	(OFF)
5.	Hot water rheostat	(LOW)
6.	Selector switch S-6 (for damper)	(OK)
7.	Evaporative condenser fan	(OFF)
8.	Evaporative condenser pump	(OFF)

OPERATING WITH WATER-COOLED CONDENSER

Preoperational Check:

1. Turn all switches OFF at control panel.
2. Check refrigerant level at water-cooled condenser receiver (75 percent full).
3. Open valves 1, 1A, and 5. Close valves 2, 2A, 3, 4, 6, and 7.
4. Check compressor oil level (1/4 to 3/4 on sight glass).
5. Check expansion valves.
6. Open steam valve to hot water converter.
7. Open hot water load valve 1/2 turn.
8. Close (ON) four small red-tipped switches on control panel.

Starting the Unit:

1.	Cooling tower fan and place on automatic	(ON)
2.	Cooling tower pump	(ON)
3.	Selector switch S-6 (3-way valve)	(DOWN)
4.	Hot water rheostat	(NORMAL)
5.	Hot water pump	(ON)
6.	Air handling unit	(ON)
7.	Refrigeration compressor	(ON)
8.	Liquidline solenoid S-2	(ON)

Operating the Unit

1. Observe suction and discharge pressures.
    a. If discharge pressure exceeds 145 psig, prepare to turn off liquid solenoid valve S-2.
    b. If compressor stops automatically on high head pressure, turn off solenoid valve S-2.
2. Adjust water load valve to 10 GPM.
3. Observe temperature, pressure and oil gages.

Stopping the Unit:

1.	Liquidline solenoid S-2 (wait for pump down)	(OFF)
2.	Refrigeration compressor	(OFF)
3.	Air handling unit	(OFF)
4.	Hot water pump	(OFF)
5.	Hot water rheostat	(LOW)
6.	Select switch S-6 (3-way valve)	(ON)
7.	Cooling tower pump	(OFF)
8.	Cooling tower fan	(OFF)

Checked by__________________________
Instructor

DETERMINE COIL CAPACITY

OBJECTIVE: Using psychrometric chart, determine coil capacity within 2 percent accuracy.

1. The capacity check formula is

$$\text{Tons} = \frac{\text{Cubic feet per min} \times \text{Specific density} \times \text{HCD}}{200 \text{ Btu/min}}$$

2. From the capacity check formula, six different values can be determined.

   a. Coil sensible tons
   b. Coil latent tons
   c. Coil tonnage
   d. Space sensible tons
   e. Space latent tons
   f. Space tonnage

3. Using the known values in the chart and the capacity check formula, solve for the values in the blank spaces of the chart below:

CFM	S.D.	T Btu	Sen Btu	Lat Btu	T Tons	Sen Tons	Lat Tons	
2500	.075	8	4	4				
2500	.074	15	7	8				
1800	.072	20	12	8				
1870	.073	7.4	5.3	2.1				
3000	.075	10	8	2				
2000	.071	12	9	3				

Checked by________________________
Instructor

DETERMINE PROPER OPERATION

OBJECTIVE: Using hygrothermograph, airflow instrument, physhrometric chart and the 25-ton trainer, perform a capacity check to within 2 percent accuracy.

CAUTIONS: 1. Do not operate any untagged valves without instructor's approval.

2. Observe all safety precautions.

1. Temperatures
   a. Supply
      (1) WB ____________________
      (2) DB ____________________
   b. Return
      (1) WB ____________________
      (2) DB ____________________
   c. Hot water load coil temp
      (1) Inlet ____________________
      (2) Outlet ____________________
   d. Hot water supply temp
2. Pressures
   a. Suction ____________________
   b. Discharge ____________________

   NOTE: Low suction pressure could indicate a restricted refrigerant line or dirty strainers.

   NOTE: High discharge pressure could indicate inoperative condenser fan.
3. Water Flow
   a. Hot water load coil ________________________ gpm
   b. Hot water reheat coil ________________________ gpm

4. **Humidity**

   a. **Supply**______________________%

   b. **Return**______________________%

5. **Air Flow**

   a. Check evaporator fan for proper operation.

   b. Check for dirty filters.

   c. Check air handler for excessive leaks.

   d. Measure airflow ________________FPM

   e. Convert FPM to CFM______________

6. Use psychrometric chart and compute operational tonnage.

   (________________tons), sensible tonnage____________________, latent tonnage

   ______________________________.

NOTE: While unit is in operation check refrigerant, water, electrical lines and components for security of mounting.

Checked by____________________________
Instructor

TROUBLESHOOTING

OBJECTIVE: Using diagnostic chart, multimeter and 25-ton trainer, troubleshoot and isolate malfunctions to the smallest repairable or replaceable item.

TROUBLE DIAGNOSIS

1. Without referring to study guide 3ABR54530-VIII-7, list the probable causes and remedies for the following troubles.

   a. Low suction pressure

      (1) Probable causes

      ____

      ____

      (2) Remedy______________________________________

      ____

   b. High suction pressure

      (1) Probable causes

      ____

      ____

      (2) Remedy

      ____

      ____

   c. Low discharge pressure

      (1) Probable causes

      ____

      ____

      (2) Remedy

      ____

      ____

d. High discharge pressure

(1) Probable causes

(2) Remedy

e. Abnormal noises

(1) Probable causes

(2) Remedy

f. **Compressor fails to start**

(1) **Probable causes**

(2) **Remedy**

g. **Compressor short cycles**

(1) **Probable causes**

2. Your instructor will place troubles in the 25-ton trainer. Observe the units operation and complete the following chart.

TROUBLE	PROBABLE CAUSE	REMEDY

TROUBLE	PROBABLE CAUSE	REMEDY

ATC-SHEPPARD AFB TEX. 70-[illegible]

545

STUDY GUIDE 3ABR54530-VIII-9

Department of Civil Engineering Training

Refrigeration and Air-Conditioning Specialist

INDIRECT EXPANSION
AIR-CONDITIONING SYSTEM

April 1975

SHEPPARD AIR FORCE BASE

11-8

Designed For ATC Course Use

DO NOT USE ON THE JOB

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Study Guides, Workbooks, Programmed Texts and Handouts are training publications authorized by Air Training Command (ATC) for student use in ATC courses.

The STUDY GUIDE (SG) presents the information you need to complete the unit of instruction, or makes assignments for you to read in other publications which contain the required information.

The WORKBOOK (WB) contains work procedures designed to help you achieve the learning objectives of the unit of instruction. Knowledge acquired from using the study guide will help you perform the missions or exercises, solve the problems, or answer questions presented in the workbook.

The STUDY GUIDE AND WORKBOOK (SW) contains both SG and WB material under one cover. The two training publications are combined when the WB is not designed for you to write in, or when both SG and WB are issued for you to keep.

The PROGRAMMED TEXT (PT) presents information in planned steps with provisions for you to actively respond to each step. You are given immediate knowledge of the correctness of each response. PTs may either replace or augment SGs and WBs.

The HANDOUT (HO) contains supplementary training materials in the form of flow charts, block diagrams, printouts, case problems, tables, forms, charts, and similar materials.

Training publications are designed for ATC course use only. They are updated as necessary for training purposes, but are NOT to be used on the job as authoritative references in preference to Technical Orders or other official publications.

Dept of Civil Engineering Tng
Sheppard AFB, Texas

SG 3ABR54530-VIII-9
April 1975

FAMILIARIZATION AND OPERATION OF INDIRECT EXPANSION AIR-CONDITIONING SYSTEMS

OBJECTIVE

Upon completing this unit of instruction, you will be able to operate, maintain, troubleshoot and identify the major components of a centrifugal air-conditioning system.

INTRODUCTION

The centrifugal compressor is a low-pressure machine using impellers for compression purposes. The refrigeration cycle is accomplished with refrigerants having a compression range of not over 30 psi. The centrifugal machine can be either motor or turbine driven and usually runs at high speeds, 3600 to 6900 rpm. They vary in capacity from less than 100 to approximately 3000 tons of refrigeration per unit. Since centrifugal units have a greater cooling capacity, they are used in larger air-conditioning installations.

Centrifugal equipment uses the indirect method of cooling. The equipment cools a fluid (usually water or brine solution) that is pumped through a cooling coil in the area to be cooled. The fluid (often called a secondary refrigerant) picks up the unwanted heat in the conditioned space and brings it back to the refrigerating equipment where it is removed and discarded.

Figure 1 (Direct Expansion System) shows the difference between the two systems. In a direct expansion system, the cooling coil (evaporator) must be relatively near the compressor. In an indirect expansion system, (figure 2), the cooling coil can be located anywhere. In fact, most indirect systems have several cooling coils located at different points throughout the building.

This supersedes SG 3ABR54530-VIII-9 and WB 3ABR54530-VIII-9-P1 thru P11, 24 August 1973.
Previous editions may be used.

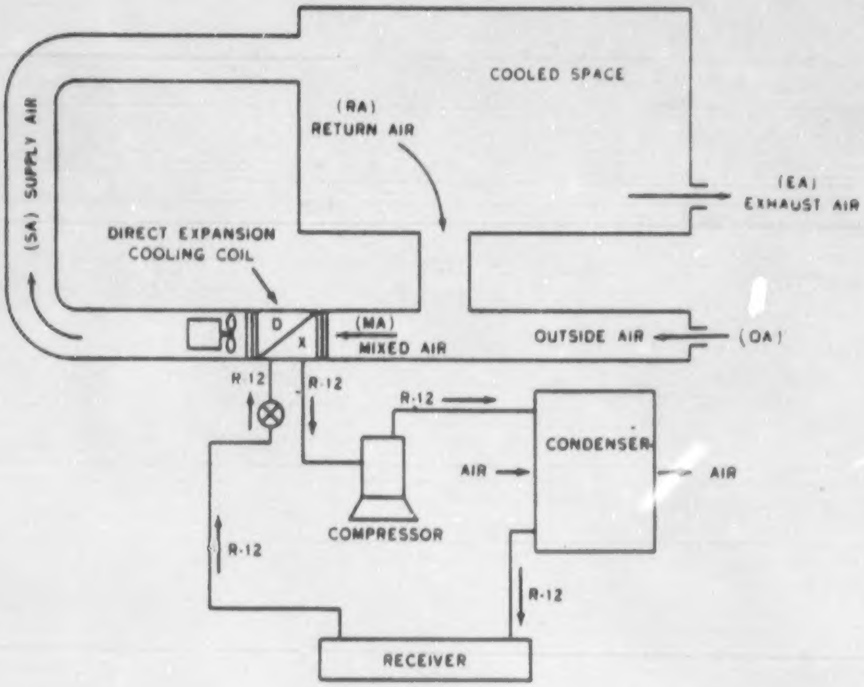

COOLED SPACE
(RA)
RETURN AIR
(EA)
EXHAUST AIR
(SA) SUPPLY AIR
DIRECT EXPANSION
COOLING COIL
D
X
(MA)
MIXED AIR
OUTSIDE AIR
(OA)
R-12
R-12
R-12
CONDENSER
AIR
AIR
COMPRESSOR
R-12
R-12
RECEIVER

Figure 1. Direct Expansion System.

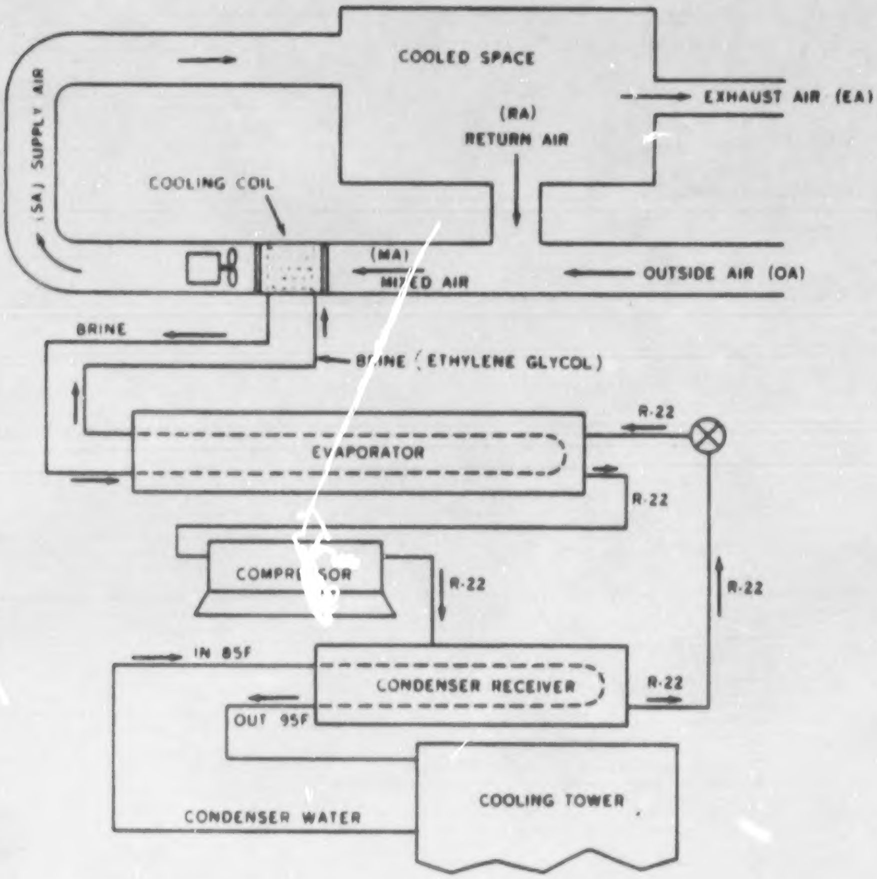

COOLED SPACE
EXHAUST AIR (EA)
(RA)
RETURN AIR
(SA) SUPPLY AIR
COOLING COIL
(MA)
MIXED AIR
OUTSIDE AIR (OA)
BRINE
BRINE (ETHYLENE GLYCOL)
R-22
EVAPORATOR
R-22
COMPRESSOR
R-22
R-22
IN 85F
CONDENSER RECEIVER
R-22
OUT 95F
COOLING TOWER
CONDENSER WATER

Figure 2. Indirect Expansion System.

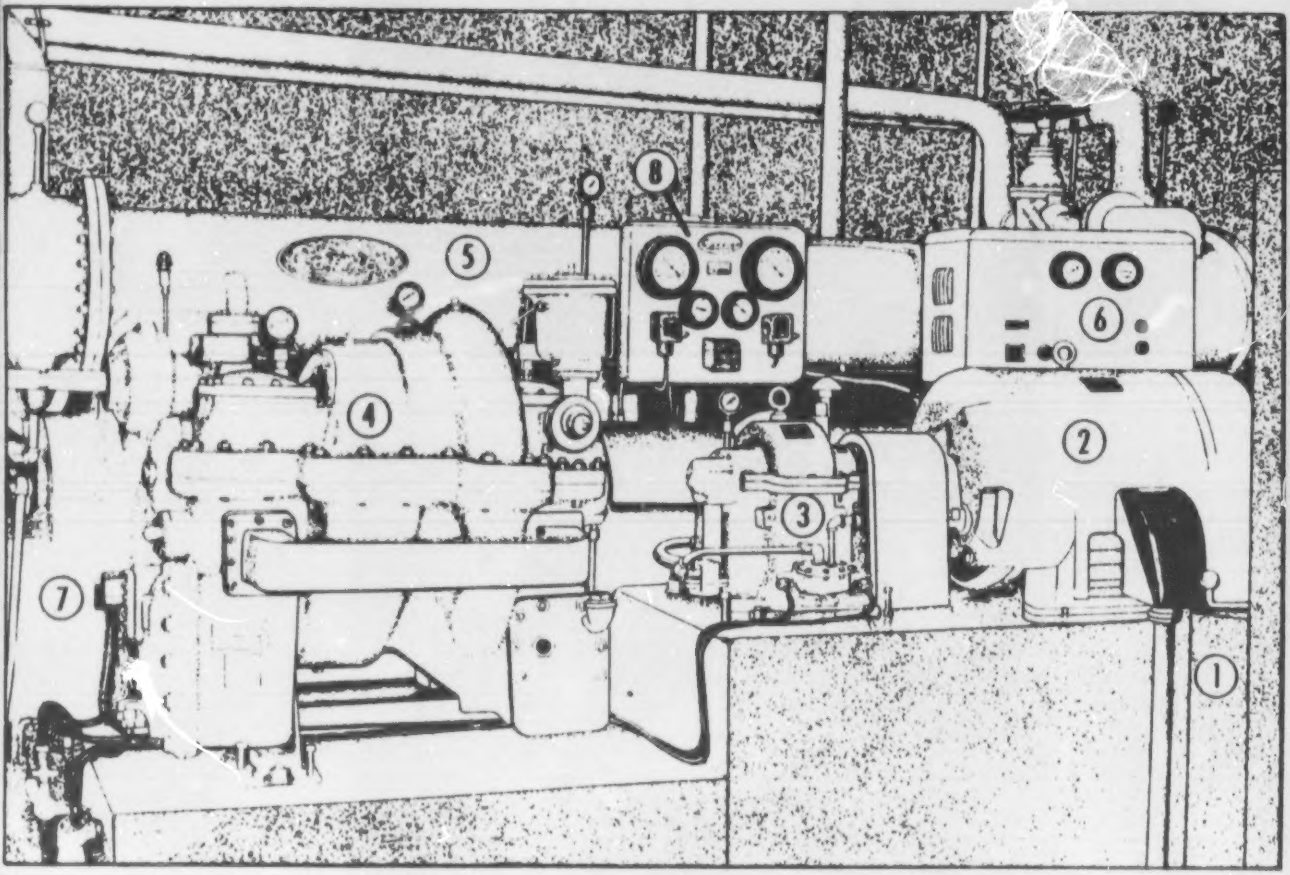


Figure 3. Centrifugal Water Chiller.

MIXED AIR PLOTS

Mixed air is the process of combining any two airflows to be introduced into some part of the system. Normally this mixture would be between RA and OA (but can include others). After being mixed, it is passed over the coil for conditioning prior to introduction to the controlled space.

Mixed air will appear on the psychrometric chart between the two conditions being mixed depending on the ratio of the air being mixed. For example, if the air mixture was based on a 50 percent mixture, the plot would appear halfway between the dry bulb lines of the two plots, see figure 4.

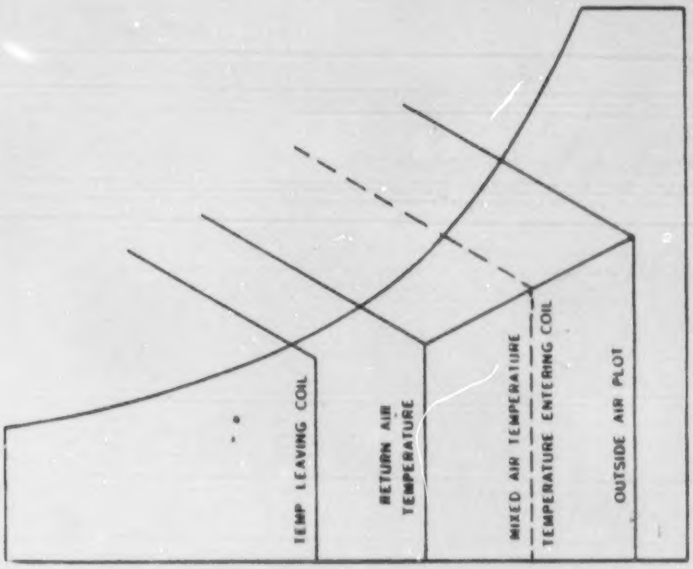

TEMP LEAVING COIL
RETURN AIR TEMPERATURE
MIXED AIR TEMPERATURE
TEMPERATURE ENTERING COIL
OUTSIDE AIR PLOT

Figure 4. Mixed Air Plot

To plot mixed air, use the following steps:

1. Draw a diagonal line to connect the % RH points of OA and RA (this will give you the % RH of MA after the DB of MA is established).

2. Find the percent of outside air in the mixed air. If 2,000 cfm outside air is added to 4,000 cfm RA, the ratio would be:

$$\frac{2000}{2000 + 4000} = \frac{2000}{6000} = \frac{2}{6} = \frac{1}{3} = 33\ 1/3 \text{ percent}$$

3. To find the dry bulb temperature difference, subtract the RA DB temperature from the OA DB temperature.

4. Find the change in temperature. Multiply the TD from step 3 by the percentage figure from step 2 for degrees of change.

5. Add the value of step 4 to the RA DB temperature to find the MA DB temperature.

6. Finish the MA plot by drawing the DB line to the diagonal line established in step 1, and finish the plot.

AIR HANDLER

The air handler in the 100 ton centrifugal trainer (see figure 5), supplies an airflow of approximately 30,000 CFM through the chill water and hot water coils. The preconditioner air handler supplies a flow of air through brine, steam, chill water coils and the air washer systems. These units are controlled by the respective controls located on the graphic control panel.

Air Distribution System

Air is drawn into the system and passed through a filter. It is drawn over a steam coil which assures a leaving temperature of 50 degrees DB, 45 degrees DP, and passes through an air washer where the remaining impurities are removed and humidity is added. In order for humidity to be added, the entering air temperature must be higher than the water temperature.

Upon leaving the air washer, the air passes through a chilled water coil being maintained at approximately 52 degrees, where grains of moisture are removed. The air enters the plenum at this temperature for comfort cooling applications. Supplemental hot water and chilled water coils are provided to maintain the desired set point for comfort conditions.

Air for equipment cooling is passed over a brine coil, being maintained at approximately 29 degrees, where additional grains of moisture are removed. Air is provided to the plenum at 35 degrees, 100 percent RH, and further conditioning is provided by return air, hot water, and chilled water coils. A diagram of the airflow, coil locations, controller locations and approximate controller settings is provided in figure 5.

Air handlers are devices that convey conditioned air to an area where it is desired. The components of an air handler may consist of the following: housing, which is usually made of some lightweight material such as aluminum or galvanized steel. This housing will have access panels for inspection and maintenance. Contained in this housing will be a fan to move the air. The most common type of fan found is the forward curved centrifugal. The type of cooling coil found in this housing will depend on the manufacturer but will be of either the direct expansion or indirect expansion type. On some systems you will find preheat and reheat coils for more precise control of the supply air temperature. These may be steam, hot water or in some cases electric. To prevent the coil from becoming dirty, the air is filtered by means of an air wash

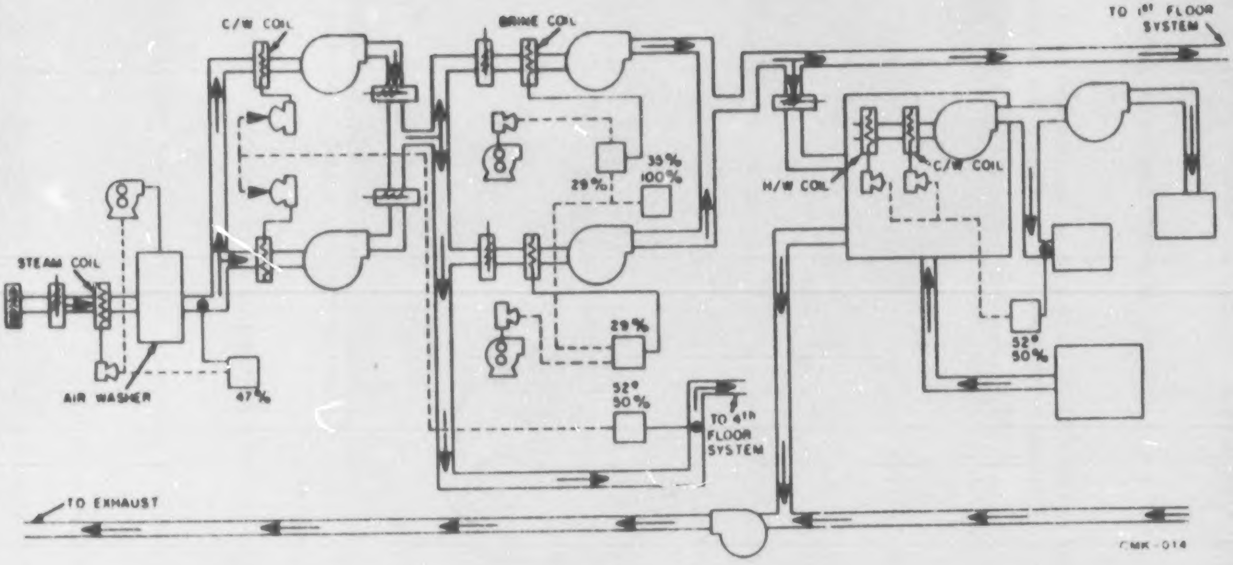

C/W COIL
BRINE COIL
TO 1ST FLOOR SYSTEM
STEAM COIL
AIR WASHER
47%
29%
35%
100%
29%
52°
50%
TO 4TH FLOOR SYSTEM
H/W COIL
C/W COIL
52°
50%
TO EXHAUST
CMK-014

Figure 5. Diagram of Typical Airflow (C)

or with the standard type of filter. To control the amount of air crossing the coil and being cooled, some units have face and bypass dampers. Working along with these dampers you may find zone dampers to control the amount of air to different zones or areas.

After the air handler and the duct work (if used) has been installed, the following checks should be made:

1. Check the fan for proper RPM, this can be accomplished by using a stroboscope or a tachometer. Compare the speed of the fan to the designed speed as stated in the specifications. If speed is not correct, adjust the variable pitch motor pulley, until the correct speed is obtained.
2. Check motor amperage and compare with the nameplate rating. A clamp on ammeter is a convenient instrument to use.
3. Check to insure that the unit is level and running smoothly with no unusual noise or vibrations.

Some of the more typical types of air handling units are shown in figures 6 through 11.

Maintenance of Air Handling Units

The main points to consider in maintenance of air handler units are (1) periodic lubrication of the fan bearings and (2) periodic cleaning of the wheel if it handles greasy or dirty air.

As a general rule, if the unit is to be operated continuously, lubricate about every 6 months. Otherwise, relubricate about once every year.

Approximately once a year after original installation the unit should be inspected as follows:

1. Check housing for signs of rust or corrosion and paint with a good rust inhibiting paint if necessary.
2. Clean the fan wheel of any accumulation of dirt which might cause unbalance and vibrations.
3. Clean the inlet vanes of dampers (when used) and see that the mechanism works freely.
4. Check bearings for wear.
5. Check to see that sheaves, fan wheel, and bearing collars are securely fastened to shaft.
6. Check and tighten mounting bolts.

555

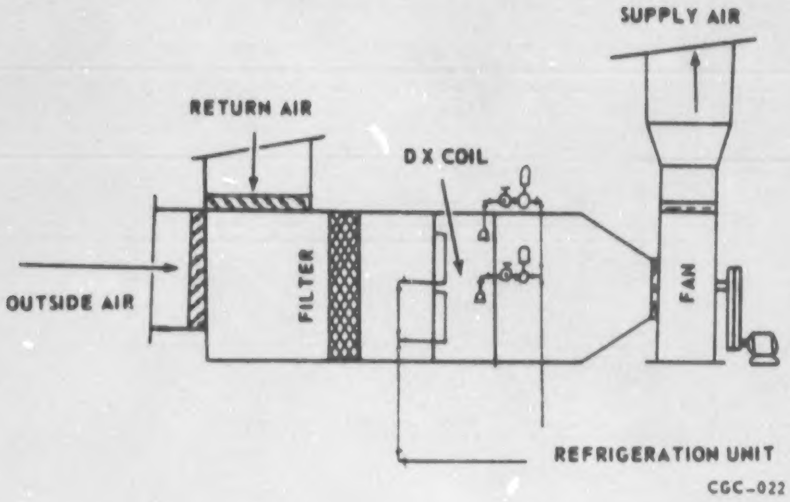

SUPPLY AIR
RETURN AIR
D X COIL
OUTSIDE AIR
FILTER
FAN
REFRIGERATION UNIT
CGC-022

Figure 6. System with central fan, bank of refrigerant coils filters, distributing duct work, refrigeration compressor and controls.

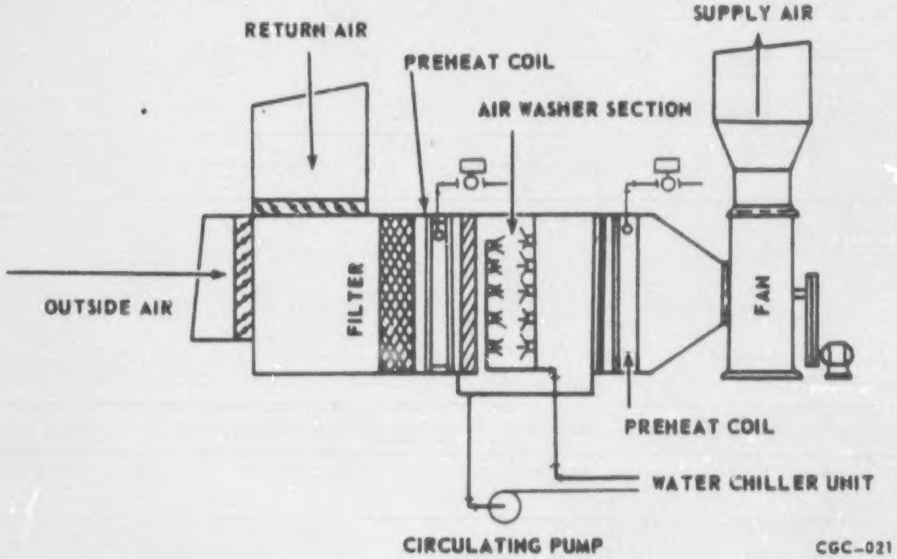

SUPPLY AIR
RETURN AIR
PREHEAT COIL
AIR WASHER SECTION
OUTSIDE AIR
FILTER
FAN
PREHEAT COIL
WATER CHILLER UNIT
CIRCULATING PUMP
CGC-021

Figure 7. System with central fan, air washer, preheat and reheat coils, filters, distributing duct work, refrigeration unit for chilling spray water, circulating pump and controls.

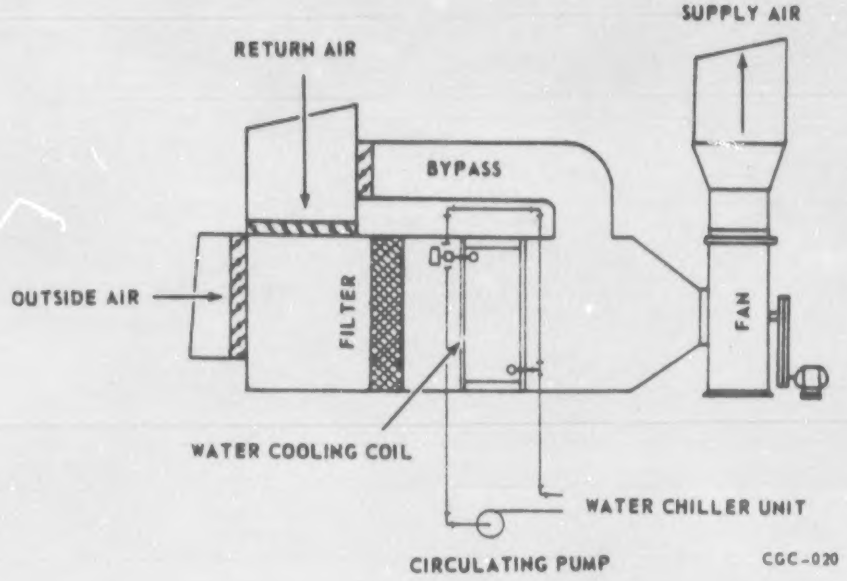

SUPPLY AIR
RETURN AIR
BYPASS
OUTSIDE AIR
FILTER
FAN
WATER COOLING COIL
WATER CHILLER UNIT
CIRCULATING PUMP
CGC-020

Figure 8. System with central fan, water cooling coil, filters, distributing duct work, refrigeration unit for chilling the water, circulating pump, bypass for control, and the controls

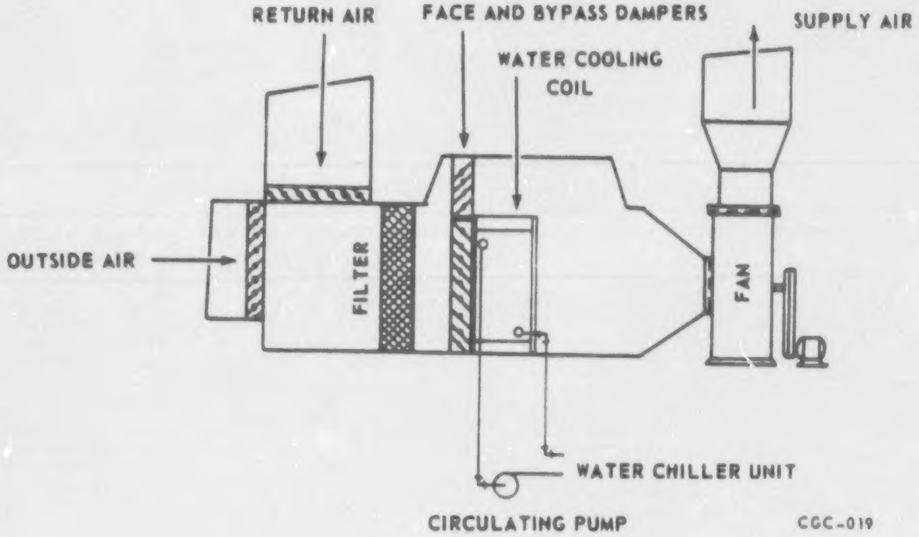

RETURN AIR
FACE AND BYPASS DAMPERS
SUPPLY AIR
WATER COOLING COIL
OUTSIDE AIR
FILTER
FAN
WATER CHILLER UNIT
CIRCULATING PUMP
CGC-019

Figure 9. System with central fan, water cooling coil, filters, distributing duct work, refrigeration unit for chilling the water, circulating pump, face and bypass dampers for control, and controls

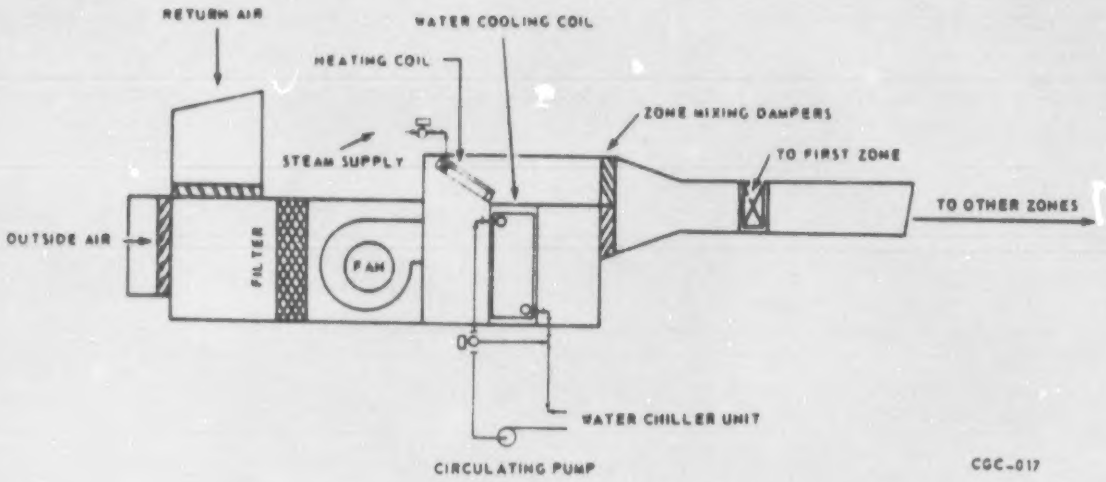

RETURN AIR
WATER COOLING COIL
HEATING COIL
ZONE MIXING DAMPERS
STEAM SUPPLY
TO FIRST ZONE
TO OTHER ZONES
OUTSIDE AIR
FILTER
FAN
WATER CHILLER UNIT
CIRCULATING PUMP
CGC-017

Figure 10. System with central fan or fans, water cooling coil, steam heating coil, filters, mixing dampers for each zone, distribution duct work, refrigeration unit for chilling the water, circulating pump and controls

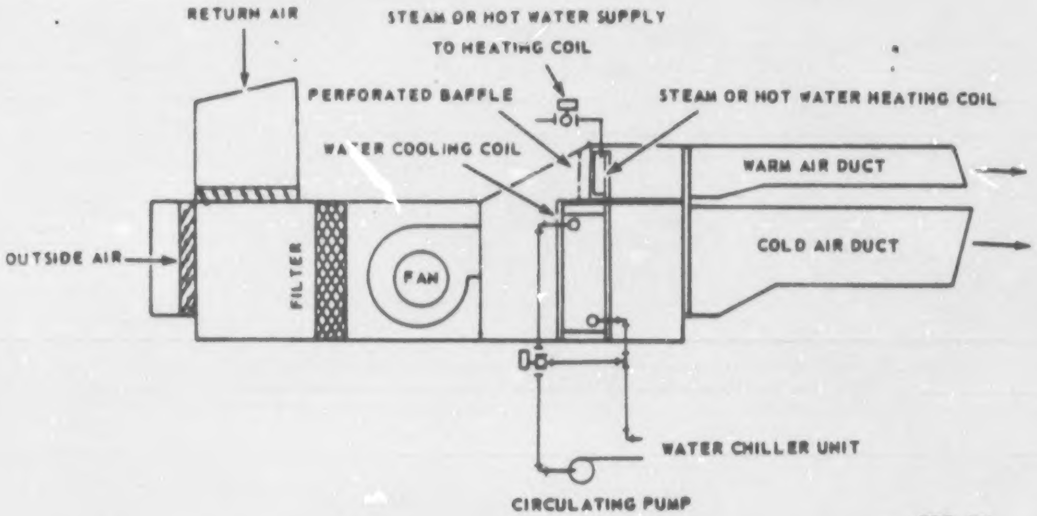

RETURN AIR
STEAM OR HOT WATER SUPPLY
TO HEATING COIL
PERFORATED BAFFLE
STEAM OR HOT WATER HEATING COIL
WATER COOLING COIL
WARM AIR DUCT
COLD AIR DUCT
OUTSIDE AIR
FILTER
FAN
WATER CHILLER UNIT
CIRCULATING PUMP
CGC-018

Figure 11. System with central fan, water cooling coil, steam or hot water coil, filters, double-duct air distribution mixing boxes for conditioned spaces, refrigeration unit for chilling the water, or a refrigeration compressor and direct expansion cooling coil for cooling air, and controls

V-BELTS. V-belts should be inspected every 3 months or every 1000 hours of operation: whichever comes first. If the belts show signs of cracking or excessive wear, they should be replaced by a new one. In the case of multiple belt systems, they should be replaced by a new set of matched belts of the same size.

The belts should be kept tight enough to prevent slippage. Avoid excessive tightening which could place too much load on the fan and motor bearings.

If fan belts are checked and found to be excessively worn, they should be replaced following the below listed procedures.

1. Move the pulley(s) together to facilitate belt removal and replacement. Never pry or roll belts on the pulley(s) as this may cause serious damage to the new belts.
2. Work the belts around the pulley by hand so that the belts are slack on the same side of the drive.
3. Move the pulleys apart until they are snug and make a preliminary check of sheave and shaft alignment. Operate the drive at a no-load for a few minutes to seat the belts and then check belt tension. Either excessively high or low tension will adversely affect the life and operation of V-belts.
4. Check sheave and shaft alignment after drive tension is applied.
5. Drive tension should be rechecked after 24 to 48 hours of operation to compensate for initial stretch and wear of the belts.
6. Periodic checks should be made of drive tension or speed ratio and tension should be restored as necessary. The change in speed ratio from no-load to full-load should not exceed 1 percent.
7. Always save used belts for emergency replacement but never mix new and used belts on a drive.
8. Keep belts as free of dirt and oil as practical.
9. Never use belt dressing on V-belts.
10. Store spare belts in a cool dry place.

Belt Tension. All V-belt drives must operate under the proper tension to produce the wedging action of the belts in the sheave grooves which gives V-belts the pulling power.

Belts which are too loose cause slippage, loss of power, loss of speed, rapid belt wear, rapid sheave wear, and possible belt squeal or howl. When a drive squeals or howls, the noise is caused by belt slippage. While slippage is usually caused by loose belts, it may be caused by excessive load, which can be determined by checking the belt tension. If it is correct, the belt is no doubt overloaded.

> NOTE: Never attempt to correct slippage by applying belt dressing. Belt dressing contains chemicals that tend to soften V-belts. While this softening process actually does increase the friction between the belt and the groove walls temporarily, it causes rapid deterioration of the rubber compounds and greatly shortens belt life.

Belts which are too tight cause damaging strain on the belts, rapid belt wear, rapid sheave wear, overheating of shaft bearings, and rapid shaft-bearing wear. It is not difficult to adjust the tension of V-belts.

The general practice for determining proper belt tension is to strike the belts with the hand. If the belts are adjusted to the right tension, they will feel "alive" and springy. If the tension is too loose, the belts will feel "dead." If there is too much tension there will be no give in the belts at all. There should be at least 1/2- to 3/4-inch slack midway between pulleys.

Belts which are found to be turned over in the sheave groove should be replaced because one or more of the cords in the strength sections are broken. These broken cords are generally caused by prying the belt on to the sheave without loosening the motor-mount bolts. The proper way or method to install V-belts has already been discussed.

MOTORS. Some motors have sealed bearings which require no maintenance, other bearings require oil for lubrication and will be equipped with oil orifice or oil cups. Also there are the type that require a grease to lubricate them.

> NOTE: Care must be taken when greasing this type bearing as damage may occur to the motor grease seals and motor itself.

Use the following procedures to grease this type motor bearing:

1. Remove bottom grease drain plug.
2. Attach grease gun to pressure grease fitting.
3. Lubricate until clean grease is seen coming out of the bottom drain plug.
4. Reinstall bottom grease plug.

BEARINGS. Some bearings require lubrication with oil and will be equipped with an oil orifice or oil cup. These should be kept full at all times. Other bearings will be equipped with the grease type bearings.

> NOTE: When lubricating this type of bearing it must be done slowly until grease appears at the seal, the bearing may overheat immediately after greasing but for a short time only.

DAMPERS. Dampers should be inspected as often as possible to insure freedom of movement and proper adjustment. They should also be inspected for rust and corrosion and painted with a good rust inhibiting paint if needed.

CONDENSATE COLLECTION PAN. The condensate pan should be checked periodically to insure proper draining of condensed moisture. Also check for amount of rust and corrosion. If rusting is occurring a good asphalt type varnish will aid in sealing the metal from corrosion.

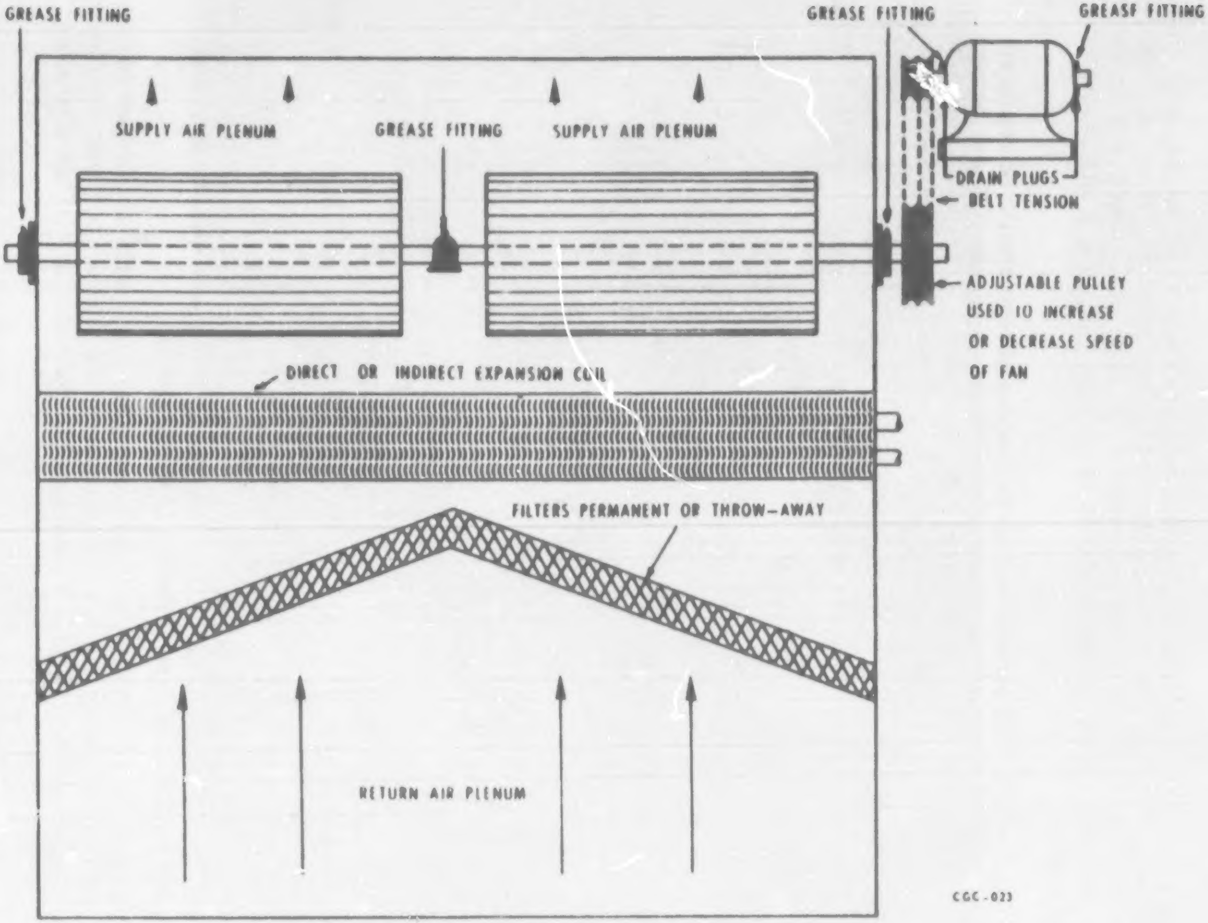

GREASE FITTING
GREASE FITTING
GREASE FITTING
SUPPLY AIR PLENUM
GREASE FITTING
SUPPLY AIR PLENUM
DRAIN PLUGS
BELT TENSION
ADJUSTABLE PULLEY USED TO INCREASE OR DECREASE SPEED OF FAN
DIRECT OR INDIRECT EXPANSION COIL
FILTERS PERMANENT OR THROW-AWAY
RETURN AIR PLENUM
CGC-023

Figure 12. Typical Air Handling Unit.

STEAM SYSTEM

Steam boilers are normally rated in horsepower, depending on the local steam requirements. Boilers are classified in two categories as to their operating pressures. A low pressure steam boiler operates at a pressure below 15 psi. The high pressure types operate from 15 psi and above. There are many types of steam boilers and various methods used to fire them. One of the most common is the horizontal fire tube type, the water being around the tubes in the shell and the fire going into the tubes. This type has a high heat transfer rate because of the large surface area with the water. Fuel or gas fired boilers are the most common.

A 125 horsepower low pressure steam boiler is used on the centrifugal air-conditioning system trainer. This boiler will operate during your practical exercises. The boiler in this type system is used to control humidity, heat water for reheat coils, and furnish steam to the cooling tower to prevent freezeup during winter operation.

For humidity control, the steam is supplied to the steam coil, (preheat coil) air passes through the coil, heating the air to a high temperature. The air then passes through an air washer system, picking up moisture and washing the air clean of any foreign particles not removed by filtration. The air is then forced through chill water coils and chilled brine coils (chill water being 45°F and the brine being 29°F), bringing the temperature to approximately 35°F at 100 percent relative humidity. These temperature and humidity figures are only instructional aids. They may vary between installations.

The hot water coils (reheat coils) are used to adjust the temperature to the rooms or equipment as desired. This is accomplished by using individual thermostats or other type temperature controllers.

BRINE CHILLER SYSTEM

The brine chiller is a 25-ton, reciprocating compressor trainer system using R-22 to chill a brine solution (ethylene glycol and water) to approximately 29°F. The brine solution is pumped to various brine coils in the preconditioner system for humidity control.

SECONDARY REFRIGERANT AND CONDENSER WATER SYSTEMS MAINTENANCE

It is very difficult to set up a definite maintenance schedule since so many operational factors must be considered. Your supervisor should familiarize you with the standing operating procedures at your installation and you must follow these recommendations.

The tubes in the condenser and cooler must receive regular attention for efficient performance and long life. Special care must be taken during the first year of operation due to dirt and other foreign materials which may have collected in the system during installation. The water treating system must operate effectively to prevent general corrosion of the tubes and piping system. Foreign material and corrosive attack can do extensive damage to the system's piping and water tubes if not effectively treated and corrected.

A special type of nylon brush should be used to clean tubes. This brush is designed to prevent scraping or scratching of the tube's inner wall. The brush is forced through each tube by hand pressure. During this cleaning process most of the scale, mud, and other foreign deposits will be loosened. The removal of such loose deposits can be accomplished by flushing with water.

If the tubes are completely covered with scale, a chemical treating process must be used to remove all foreign deposits. The manufacturer's maintenance manual will give information on the type and strength of chemical solution to use on their designed units.

Condenser

It is recommended that the condenser tubes be brushed at least once a year. Hourly checks must be made between the difference of the leaving condenser water temperature and the condensing temperature. If at full-load operation, this difference exceeds the design value, fouling of tube surfaces is taking place. Should the leaving condenser wate temperature be hard to maintain, cleaning of the condenser tubes is recommended.

SERVICING. The following procedures should be followed in cleaning condenser tubes.

1. Shut off the main line inlet and outlet valves.
2. Drain water from condenser through the water box drain valve. Open the vent cock in the gage line or remove the gage to help draining.
3. Remove all nuts from the water box covers, leaving two on loosely for safety.
4. Using specially threaded jacking bolts, force the covers away from the flanges. As soon as the covers are loose from the gaskets, secure a rope to the rigging bolt in the covers and an overhead support. Remove the last two nuts and place the cover on the floor.
5. Scrape both the cover and the matching flange to free any gasket material.
6. Remove the water box division plate by sliding it out from its grooves. Caution should be used in removing this plate: it is made of cast iron. Penetrating oil may be used to help remove the plate.
7. Use a nylon brush or equal type on the end of a long rod. Clean each tube with a scrubbing motion and flush each tube after the brushing has been completed.
8. Replace the division plate after first shellacking the required round rubber gasket in the two grooves.
9. Replace the water box covers after first putting graphite on both sides of each gasket as this prevents sticking of the gaskets to the flanges.

CAUTION: Care must be taken with the water box cover on the water box end to see that the division plate matches the rib of the flanges.

10. Tighten all nuts evenly.

11. Close the drain and gage cock.

12. Open the main line water valve and fill the tubes with water. Operate the pump, if possible, to check for leak-tight joints.

REPAIR. Retubing is about the only major repair that is done on the condenser. This takes a high degree of skill and may require the services of a manufacturer's qualified repairman.

Evaporator or Cooler

You will be required to make frequent checks of the chilled water temperatures in the evaporator. If these temperature readings at full-load operation begin to vary from the designed temperatures, fouling of the tube surfaces is beginning and cleaning is required when leaving chilled water temperature cannot be maintained.

In cleaning the evaporator, it is recommended that the tubes be cleaned at least once a year, which may vary with local operating conditions. Cleaning schedules should be outlined in the standard operating procedures.

SERVICING. Servicing procedures for shell and tube type evaporators and condensers are the same since all shell and tube containers are built and operate on similar principles.

REPAIR. Retubing is about the only major repair that is done on the evaporator. This work should be done by a qualified refrigeration repairman or a manufacturer's representative.

CENTRIFUGAL AIR-CONDITIONING SYSTEM

Illustrated in figure 3 is a centrifugal machine. As you can see, it is a compact assembly made up of eight major components. A list of these components and their function is as follows:

1. Drum control: Used to increase or decrease the speed of the motor, by varying the resistance to the motor.

2. Drive: An electric motor or turbine which supplies power to drive the compressor.

3. Speed increaser (Terry Gear): A separate component between the motor and compressor to obtain proper compressor speed with standard motor.

4. Compressor: Centrifugal type which compresses the evaporated refrigerant and discharges it to the condenser.

5. Shell and tube type condenser: Liquefies the refrigerant received from the compressor.

6. Purge recovery unit: A compact assembly that removes noncondensable gases and moisture from the condenser and returns the refrigerant to the cooler, while the noncondensable gases and moisture are discharged to the atmosphere.

7. Shell and tube type evaporator or cooler: Cools the chilled water passing through the tubes by the evaporation of the refrigerant in which the tubes are immersed.

8. Control panel: Location of electric or pneumatic controls used for operation of the various components of the machine are mounted on the panel.

The economizer (not shown in figure 3) is located in the cooler below the purge unit. It partially cools the condensed refrigerant before passing it on to the evaporator. Evaporation in this chamber helps improve the cooling efficiency of the machine. Vapors from the economizer are piped to the second stage of the compressor.

Drum Controller

The secondary drum controller is used to adjust the amount of resistance in the rotor circuit of the motor. Resistors are used with the drum to provide speed regulation and act as an energy dissipating unit. The maximum amount of energy turned into heat in the resistors amounts to about 15 percent of the motor rating. The grid resistors perform two functions: First, to limit the starting current when the motor is accelerating from standstill to operating speed; and, second, to regulate the operating speed of the motor. The drum adjusts the amount of resistance in the rotor circuit. Resistors are provided with connection lugs corresponding to the connection lugs on the drum. The resistors limit the motor starting inrush current to 150 percent of full load motor starting current and provide 25 percent speed reduction below full load speed of the motor. The drum resistors are connected to the slip rings. The Cutler-Hammer drum controller provides balanced resistor speed control points which are clearly indicated on the drum head. Drum points that are not numbered, are unbalanced resistor points for acceleration only. The motor should not be permitted to dwell on any of the unbalanced speed points as these points serve only to limit the acceleration current drawn by the motor. An electrical interlock circuit in the drum consists of three contact fingers and cylinder contacts below the main contacts. It also provides the electrical connection in the full resistance position to allow the primary switch or circuit breaker to apply power to the motor. The interlock prevents starting the motor unless all resistance is in the motor.

OPERATION. Always bring the drum control lever to the "off" position before pressing "start" button. Manual starting of the machine at the motor location assures the operator complete supervision of the unit. Interlocking wiring connections between drum controller and circuit breaker make it necessary to return drum control to full low speed position (all resistance in the motor) before breaker can be closed while oil pressure switch is bypassed holding "start" button closed. Releasing "start" button before oil pressure switch closes will cause breaker to trip out - hence a false start.

To regulate speed, move the drum control lever to next higher balanced speed point (marked points) and pause only about one second on each unbalanced point (unmarked points). Do not allow motor to run on unbalanced speed points due to possible pulsating torque. This causes unnecessary wear on bearing, gears and couplings.

MAINTENANCE. Isolate all power before attempting any maintenance. Drum contactors should be checked for alignment, kept lubricated with a thin coating of vasoline and kept free of excessive dirt and dust.

Motor

The motor drive unit is a polyphase, induction motor, 440 volts, 1755 RPM, 120 amps, manufactured by Ideal Electric Manufacturing Company.

The purpose of the motor is to drive the compressor at proper speed as load requirements demand.

Speed Increaser

The speed increaser is a separate component mounted between the compressor and motor. (The gears are speed increasers required to obtain the proper compressor speed through the use of standard speed motors.) In general, the gears are of the double helical type, properly balanced for smooth operation, and pressure lubricated. The gear wheel and pinion are enclosed in an oil-tight case which is split at the horizontal center line. Lubrication is from a gear-type oil pump. The unit has an oil level sight glass, pressure gage, an externally mounted oil strainer and oil cooler.

LUBRICATION. The oil pump is a gear type. When assembling, care must be taken to see that the paper gasket between the pump body and brackets is of the proper thickness. A gasket which is too thick will reduce pump capacity and cause an oil pressure failure. An excessively thin gasket will cause unnecessary load on the gears, resulting in wear and destruction of the gears. Writing paper makes a good gasket when shellacked in place. Never use a rubber gasket on any oil joint.

A good gear oil must be used for the lubrication of high speed gears. The oil must be kept clean by filtering, and filters must be changed as often as possible. The temperature of the oil should be kept approximately 150°F - 180°F. Water cooling should be used whenever necessary to keep the temperature within these limits.

Selection of the best grade of oil for use on a gear is based on journal speeds, tooth speeds, and clearances. In general, it is better to use an oil that is too heavy than one too light. The gears will be somewhat warmer, but the heavier oil will take care of the higher temperature if it is not more than a few degrees. The heavier oil is rated at 400 to 580 seconds viscosity.

WATER COOLING OF GEARS. Water cooling of gears is accomplished by circulating water through water jackets cast in the ends of the gear casing or by means of either an internal or external oil cooler. This system is connected to a supply of cool, clean water at a minimum pressure of 4 pounds. A regulating device must be installed in the water supply line. The discharge line should have free outlet without valves to avoid possibility of excessive pressures on the system. Piping must be arranged so that all the water can be drained or blown out of the water jackets or cooler if the unit may be subjected to freezing temperatures.

MAINTENANCE. Inspect to see that both the driving and driven machines are in line. If you are not sure that alignment is correct, check this point with gages. Try out the water cooling system to see if it is functioning properly. When starting, see that you have sufficient oil in the gear casing and that the oil pump gives required pressure (4 to 8 lbs). When the temperature of the oil in the casing reaches 100°F, turn on the water cooling system. Add sufficient oil from time to time to maintain the proper oil level. Never allow the gear wheel to dip into the oil.

Regular cleaning of the lubrication system and tests of the lubricant are essential. Clean the strainer at least once a week and oftener if necessary. The manufacturer recommends the gear case be drained and completely cleaned every two - three months. Refill with new filtered oil. From time to time, between oil changes, samples of oil should be drawn off and the oil checked. If water is present, the water should be drawn off; and, if there is a considerable amount of water in the oil, remove all oil and separate water from the oil before it is used again.

All working parts are easily accessible for inspection and repair except the oil pump. If the occasion arises to dismantle the gears, extreme precautions must be taken to prevent any damage to gear teeth. The slightest bruise will result in a noisy operation. When the gears are removed, place them on a clean cloth-covered board and block them so that they cannot roll off. Cover gears with cloth for protection purposes.

Bearing shells and oil slingers are marked and should be reinstalled in their proper places. Gaskets are used between the oil pump bracket and oil pump, and under hand hole covers. All parts must be clean when reassembling. Make sure that no metal burrs or cloth lint are present on any part of the unit. Coat faces of flanges with shellac before they are bolted in place. A thin coat of shellac on the bearing supports will prevent oil leaks at these places.

When bearings are worn, they must be immediately replaced. Worn bearings will cause gears to wear. Bearings are interchangeable and when new bearings are installed, the gears are restored to their original center distance and alignment. It is not recommended to rebabbitt bearings; the heat required to rebabbitt bearings will cause some distortion of the bearing shell. Do not renew one bearing alone; always renew in pairs. This will help eliminate tooth misalignment.

"Cinch" fittings are used on all pipes connected to the oil pump bracket: use this type on all replacements. Threaded fittings may cause the bracket to be pulled out of line, causing noisy operation and wear on gears.

Couplings should not be driven on or off the gear or pinion shafts, as hammering may injure both surfaces. Provisions have been made for using a jacking device for putting on or removing couplings from shafts.

Gear tooth contact and wear should be uniformly distributed over the entire length of both gear and pinion helixes. If heavier wear is noted on any portion of the helixes or any part of the tooth face, it may indicate improper setting of the gear casing, misalignment of connecting shafts, vibration, excessive or irregular wear on the bearings, or poor lubrication. Should gear teeth become damaged during inspection or operation, remove burrs by use of a fine file or oilstone. Never use these tools to correct the tooth contour.

Misalignment, poor lubrication, and vibration can cause pitting of tooth surfaces or flaking of metal in certain areas of the gears. If this happens, check alignment and remove all steel particles.

Couplings

The couplings used to connect the motor to the speed increasing gears and from the gears to the compressor are self-aligning couplings. The coupling is of the flexible geared type, consisting of two externally geared hubs that are pressed on and geared to the shafts. These hubs are enclosed by a two-piece, externally geared, floating cover which functions as a single unit when the halves are bolted together. The cover is supported on the hub teeth during operation. A spacer or spool piece is used with the cover for the compressor coupling. The hub teeth and cover teeth are engaged around the complete circumference and the cover and shafts revolve as one unit. The cover and each shaft are free to move independently of each other within the limits of the coupling, thus providing for reasonable angular and offset misalignment as well as end float.

The amount of misalignment that the coupling will handle without excessive stressing varies with the size of the coupling. In all cases, however, it should be treated as a coupling taking care of incidental misalignment and should never be considered as a universal joint.

Flexible couples are generally the type used on most centrifugal units. They will insure long life if properly maintained. The two most important operating services to insure long life are proper lubrication and proper alignment.

Centrifugal Compressor

The easiest way to understand the functions of a centrifugal compressor is to think of it as a centrifugal fan of the type used for forced and induced draft. Like the fan, the compressor takes in gas and whirls it at a high speed, which compresses the gas by centrifugal force. The high velocity of the gas leaving the impellers is converted to a pressure exceeding the inlet pressure. At maximum speed, the compressor will produce a suction temperature of approximately 60°F below the condensing temperature of R-11. Changing speed varies suction temperature.

The compressor casing and the various stationary passages inside the compressor casing are made of cast iron. The compressor shaft is made of hard steel, turned and ground with keyways for each impeller, while the impellers are of the built-up type. The hub disc and cover are machined steel forgings. The blades are sheet steel formed to curve backward with respect to the direction of rotation and riveted to the hubs and covers. After assembly, the wheels are given a hot-dipped lead coating to reduce corrosion damage. The compressor rotor assembly consists of the shaft and impellers. It runs in two sleeve-type bearings.

Thermometers are inserted in the top of each bearing cover for obtaining bearing temperature. Each bearing also has two large oil rings to assure lubrication when the machine is starting up or slowing down.

Brass labyrinth packing in the diaphragms prevents interstage leakage of gas. Similar packing on the shaft at the ends of the casing restricts the flow of gas between the main compressor casing and the bearing chambers.

In operation, the pressure differential across each impeller produces an axial thrust toward the suction end of the compressor. This thrust is supported by a "Kinsbury" thrust bearing at the suction end of the shaft. (See figure 13.)

COMPRESSOR LUBRICATING SYSTEM. The compressor has a forced lubrication system (figure 13) including oil pump, bearing oil rings, pressure regulating valves, etc. The entire oiling system is housed within the compressor casing and the oil is circulated through cored openings, drilled passages, or fixed copper lines. This eliminates all of the usual external lines and their danger of possible rupture, damage, or leakage. All of the oil for the lubricating system is circulated by a helical gear pump, which is submerged in the main oil reservoir. The simple, positive drive assures ample oil for pressure lubricating and cooling all journal bearings, thrust bearings, and seal surfaces.

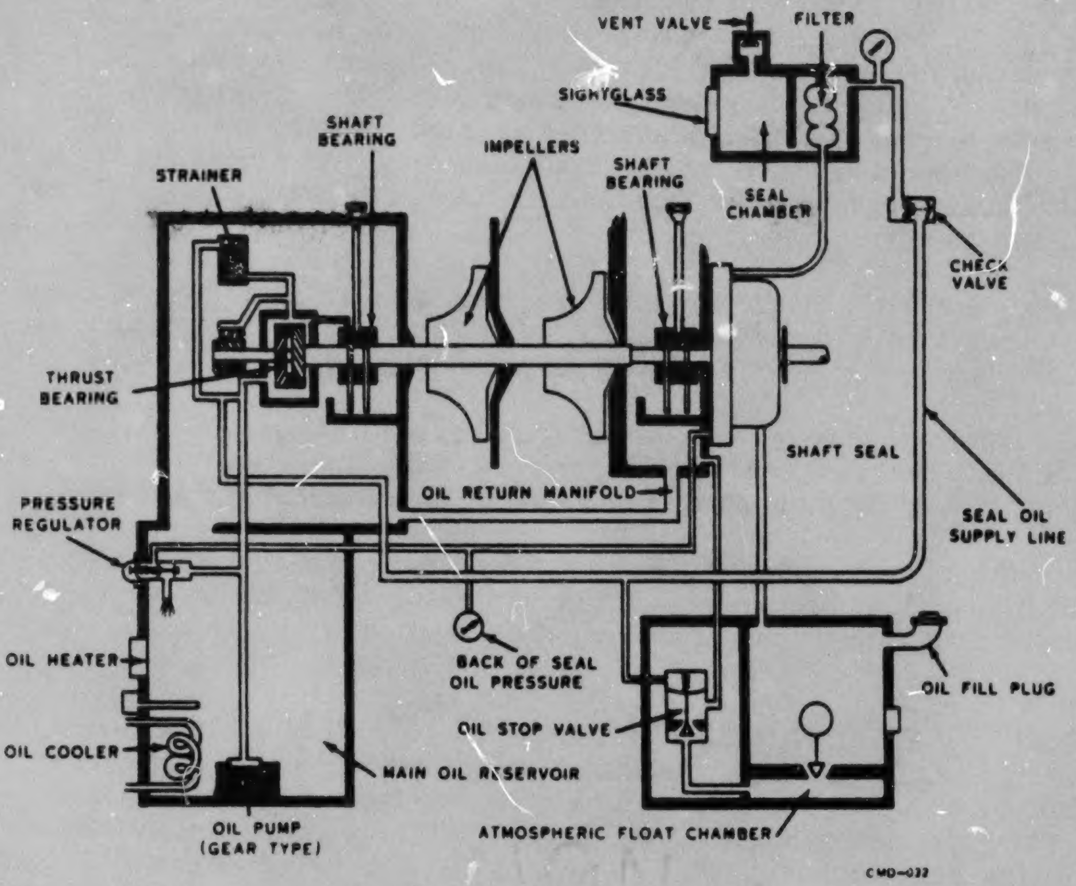

VENT VALVE
FILTER
SIGHTGLASS
SHAFT BEARING
IMPELLERS
SHAFT BEARING
STRAINER
SEAL CHAMBER
CHECK VALVE
THRUST BEARING
SHAFT SEAL
OIL RETURN MANIFOLD
PRESSURE REGULATOR
SEAL OIL SUPPLY LINE
BACK OF SEAL OIL PRESSURE
OIL HEATER
OIL FILL PLUG
OIL STOP VALVE
OIL COOLER
MAIN OIL RESERVOIR
OIL PUMP (GEAR TYPE)
ATMOSPHERIC FLOAT CHAMBER
CMD-032

Figure 13. Oil Piping Diagram

The reservoir which houses the oil pump is an integral part of the compressor casing and is accessible through a cover plate on the end of the compressor. Circulating water cooling coils are fitted to the cover plate to maintain proper oil temperature.

A high grade turbine oil, such as DTE heavy medium or approved equivalent, is recommended for centrifugal compressors. To be sure of specifications on grade and type of oil to use, it is advisable to refer to the manufacturer's maintenance manual. The oil in the centrifugal compressor should be changed annually.

If a machine is to be started for the first time, or if all the oil has been drained from the unit, the following lubrication procedures are recommended:

1. The machine pressure must be atmospheric.

2. The cover on the front bearing at the coupling end of the compressor is removed and one gallon of oil is poured into the front bearing level.

3. Fill the seal oil pressure chamber by removing the cover.

4. Remove the cover from the rear bearing and pour oil into the chamber until the indicated height is reached as recommended on the plate on the pump chamber.

5. Fill the atmospheric float chamber through the connection on the side of the chamber until oil shows in the sight glass. (See figure 13.)

6. Pour a small amount of oil into the thrust bearing housing by removing the strainer cap and pouring into the strainer.

Under normal operating conditions, the following lubrication procedures are recommended:

1. Replacement of the oil filter regularly, depending on the length of operation and the condition of the filter.

2. If, at any time, oil is withdrawn from the machine, replace it with new oil.

3. Clean and inspect the strainer in the thrust bearing at least once a year.

4. Replace the complete oil charge at least once a year.

5. After shutdown periods of more than a month, remove the bearing covers and add one quart of oil to each bearing well before starting.

OIL DRAINAGE. To drain the oil system, allow the machine to warm up until the temperature is approximately 75°F. The machine must be at atmospheric pressure. The pump chamber is drained by removing the drain plug. Replace the plug, then drain the atmospheric float chamber in the same manner. By draining these two chambers, practically all of the oil is removed. The oil left in the bearing wells and seal reservoir is useful for keeping the bearing in satisfactory condition and as a sealing oil.

To keep the machine in the best operating condition, the following precautions must be observed:

1. The electric heater in the oil pump chamber must be turned on during shutdown periods, and must be turned off when the cooling water is turned on. The purpose of this heater is to keep the R-11 and oil separated.

2. Do not overcharge the system with oil. The oil level will fall as the oil is circulated through the system; but under normal operation, the oil level will increase approximately 7 percent in volume as the refrigerant becomes absorbed in it. The oil level in the machine will be approximately one-half sight glass.

3. Oil can be added to the filling connection (figure 13) on the side of the atmospheric float chamber only while the machine is in operation and the atmospheric float chamber return valve is open.

COMPRESSOR SHAFT SEAL. A shaft seal is provided where the shaft extends through the compressor casing. The seal is formed between a ring called the rotating sealing seat fitted against a shoulder on the shaft and the stationary sealing seat attached to the seal housing through a flexible member or bellows assembly. The contact faces on these seal seats are carefully machined and ground to make a vacuum tight joint A spring, called the multileaf seal spring, moves the stationary seal seat into contact with the rotating seal seat to make the proper seal when the compressor is shut down. A floating ring is located between the hub of the stationary sealing seat and the hub of the rotating sealing seat. A seal oil reservoir and filter chamber are attached to the compressor housing above the seal to provide oil to maintain a head of oil to the seal surface during shutdown periods.

Simply, the shaft seal consists of two highly polished metal surfaces which are held tightly together by a spring during shutdown and are separated by a film of oil under pressure during operation. The positive supply of oil from the oil pump during operation and the seal oil reservoir during shutdown prevents any inward leakage of air or outward leakage of refrigerant. In addition, the low oil pressure safety control will automatically stop the compressor if the oil pressure to the seal falls below a safe minimum.

Condenser

The condenser is a shell and tube type similar in construction to the cooler. The primary function of the condenser is to receive the hot refrigerant gas from the compressor and condense it to a liquid.

A secondary function of the condenser is to collect and concentrate noncondensable gases so that they may be removed by the purge unit. The top portion of the condenser is baffled. This baffle encloses a portion of the first water pass. The noncondensable gases rise to the top portion of the condenser because they are lighter than refrigerant vapors and because it is the coolest portion of the condenser. (See figures 14 and 15.)

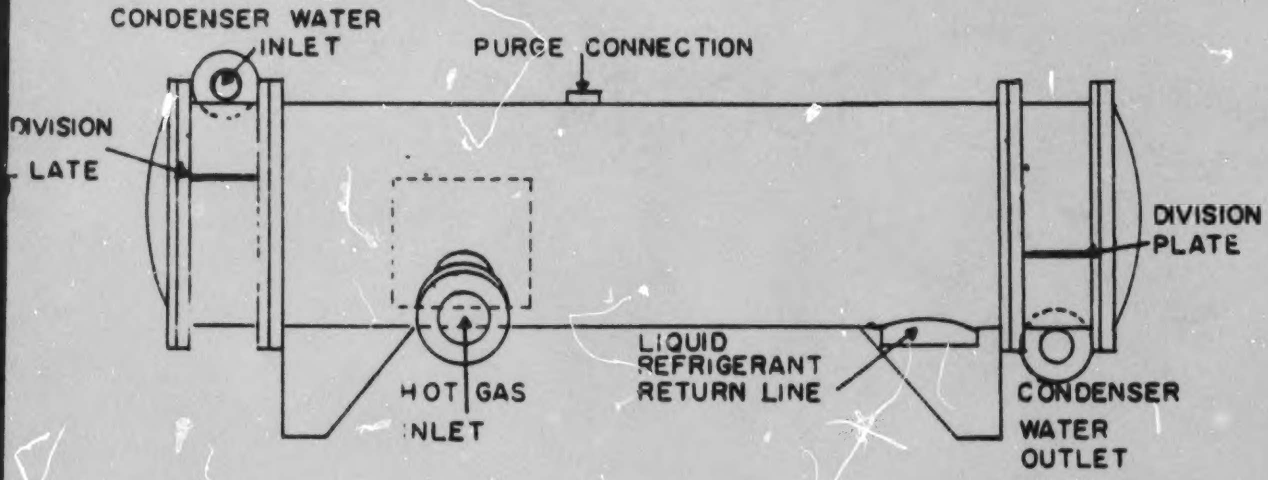


Figure 14. Condenser Diagram

A perforated baffle or distribution plate (figure 15) is installed along the tube bundle to prevent direct impact of the compressor discharge on the tubes. The baffle also serves to distribute the gas throughout the length of the condenser.

The condensed refrigerant leaves the condenser through a bottom connection at one end and flows into the condenser economizer float chamber. (See figure 14.)

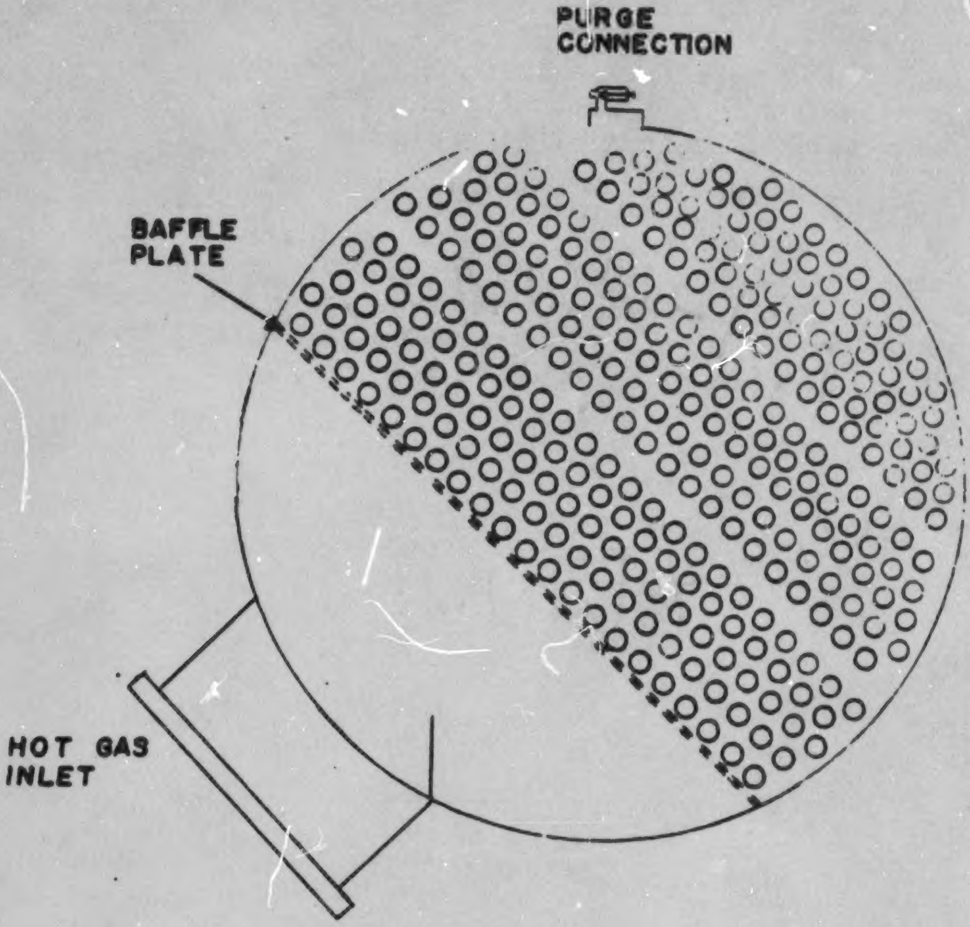


Figure 15. Cross Section of Condenser (3 Pass)

The water boxes (figure 14) of all condensers are designed for a maximum working pressure of 200 Psig. They are provided with the necessary division plates to give the required flow. Water box covers may be removed without disturbing any refrigerant joint since the tube sheets are welded into the condenser and flanges. Vent and drain openings are provided in the water circuit.

The condenser is connected to the compressor and the cooler shells with expansion joints to allow for differences in expansion between them.

Purge Unit

The presence of even a small amount of water in a refrigeration system must be avoided at all times, otherwise excessive corrosion of various parts of the system may occur. Any appreciable amount of water is due to a leak from one of the water circuits.

The pressure within a portion of the centrifugal refrigeration system is less than atmospheric; therefore, the possibility exists that air may enter the system. Since air contains water vapor, a small amount of water will enter whenever air enters.

The function of the purge system is to remove water vapor and air from the refrigeration system and to recover the refrigerant which is mixed with these gases. The secondary function of the purge unit is to pressurize the centrifugal machine for leak testing.

The air is automatically purged to the atmosphere. The refrigerant is condensed and automatically returned to the cooler as a liquid. Water, if present, is trapped in a compartment of the purge separator unit from which it can be drained manually. Thus, the purge recovery system maintains the highest possible refrigerating efficiency.

PURGE RECOVERY OPERATION. The purge recovery operation is automatic, once the purge switch is turned "ON" and the four valves listed below, and referred to in figure 16, are opened.

1. Service valve on main condenser.
2. Hand valve in suction line.
3. Hand valve in the return liquid refrigerant line.
4. Service valve on economizer in return liquid refrigerant line.

(NOTE: Water drain hand valve must be closed during normal operation.)

If there should be an air leak in the system, operation of the purge unit will remove the air. It is recommended that the operator stop the purge unit at intervals and shut-off valves (2) and (3) listed above, to check for leaks in the purge system. A tight machine will not collect air no matter how long the purge unit is shut off.

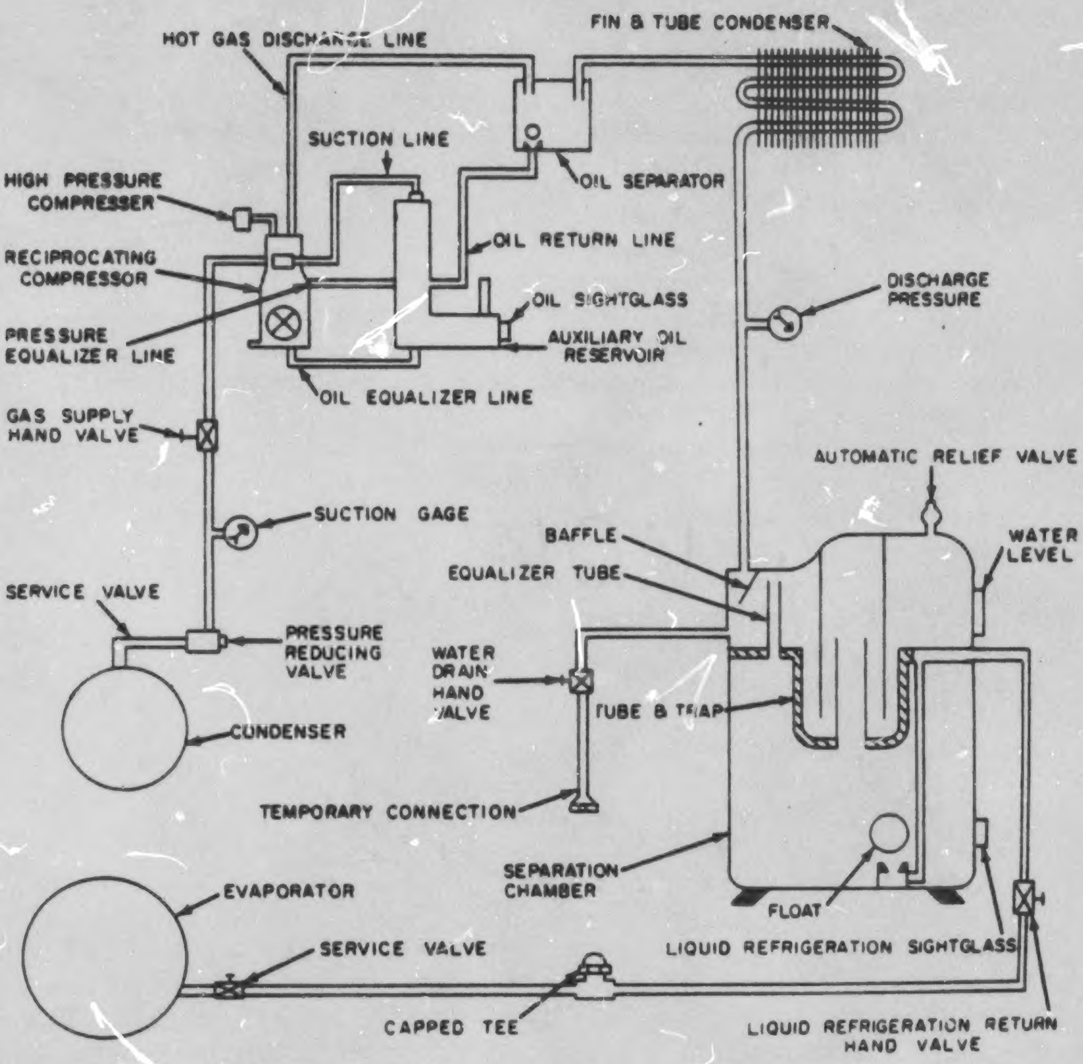

HOT GAS DISCHARGE LINE
FIN & TUBE CONDENSER
SUCTION LINE
HIGH PRESSURE COMPRESSER
OIL SEPARATOR
RECIPROCATING COMPRESSOR
OIL RETURN LINE
OIL SIGHTGLASS
DISCHARGE PRESSURE
PRESSURE EQUALIZER LINE
AUXILIARY OIL RESERVOIR
OIL EQUALIZER LINE
GAS SUPPLY HAND VALVE
AUTOMATIC RELIEF VALVE
SUCTION GAGE
BAFFLE
WATER LEVEL
EQUALIZER TUBE
SERVICE VALVE
PRESSURE REDUCING VALVE
WATER DRAIN HAND VALVE
TUBE & TRAP
CONDENSER
TEMPORARY CONNECTION
SEPARATION CHAMBER
EVAPORATOR
FLOAT
SERVICE VALVE
LIQUID REFRIGERATION SIGHTGLASS
CAPPED TEE
LIQUID REFRIGERATION RETURN HAND VALVE

Figure 16. Purge Unit

Presence of air in the Centrifugal unit is shown by an increase in head pressure in the condenser. The pressure can develop suddenly or gradually during machine operation. Checking the difference between leaving condenser water temperature and the temperature on the condenser gage can be used to determine the presence of air. A sudden increase between these temperatures may be caused by air. In some instances, a sudden increase in cooler pressure over the pressure corresponding to cooler temperature during operation, may be caused by air leakage.

Small air leakages are very difficult to determine. It may take one or more days to detect an air leakage in the machine. A leak that shows up immediately or within a few hours is large and must be found and repaired immediately.

Refrigerant loss depends on operational conditions; therefore, these conditions have a determining effect on refrigerant losses. The operator should be very careful in maintaining his log on refrigerant charged and the shutdown level in the cooler. In this manner, he can determine the time a leak develops, refrigerant loss, find the cause, and correct the trouble.

If the machine operates with a pressure in the condenser and has a slight air leak during normal operation but indicates a large gain of air when shut down under vacuum, a serious leak exists in the high pressure side of the system. Such a leak will be to the outside during operation and cause a large amount of refrigerant loss. The cause must be found and corrected.

Moisture removal by the purge recovery unit is just as important as air removal. The moisture may enter the machine by humidity in the air that can leak into the machine or by a water leak in the cooler or condenser. If there are no water leaks, the amount of water collected by the purge unit will be small (one ounce per day) under normal operating conditions. If large amounts of water are collected by the purge unit (one-half pint per day), the machine must be checked for leaky tubes. Water must be removed manually by opening water drain hand valve. If any water does collect, it should appear in the sight-glass and should be drained. Water can be removed more rapidly when the machine is stopped than when running. If the machine is collecting large amounts of moisture, it is advisable to run the purge unit a short time after the machine is stopped and before it is started. Running the purge unit before the machine is started will help to reduce purging time, after the machine is started.

The automatic relief pressure valve is related to room temperature as shown in Table 1, and can be adjusted by a screwdriver after removing the top cover of the purge unit casing. For recommended pressures within the condenser pressure limits, refer to Table 1.

The pressure reducing valve is adjusted to produce a suction pressure on the purge unit and will not allow condensation in the suction line. If condensation does occur, the condensate will collect in the crankcase of the purge compressor, causing a foaming and excessive oil loss. Table 1, shown below, can be used as a guide for setting the pressure reducing valve.

If the pressure reducing valve is wide open, there will be a pressure drop of a few pounds across the valve and the suction pressure cannot be adjusted higher than a few pounds below the machine condensing pressure.

Room Air Temperature	65	75	85	95	105	115
Suction-Pressure (Maximum Allowable)	5 Inch Vacuum	0-lb 0-lb Gage	3.5 lb Gage	7 lb Gage	Wide Open	Wide Open
Relief Pressure by Adjustment of Automatic Relief Valve	75-80	75-80	95-100	95-100	105 - 110	105 - 110

Table 1

LUBRICATION. The purge unit compressor and centrifugal compressor use the same type and grade of oil. Oil can be added to purge compressor by closing the hand valves, (2) and (3) listed under Purge Recover Operation, removing the plug in the top of the oil sight glass, and adding oil. Draining the oil can be accomplished by removing the oil plug below the purge compressor. The oil level can be checked by a showing of oil at any point in the sight glass while the compressor is running or shut-down. The level of oil will fluctuate accordingly. The oil level should be checked daily.

MAINTENANCE. Other components that must be closely checked in the purge recovery unit are as follows:

1. Belt tension

2. Relief Valve for tightness when closed to prevent loss of refrigerant.

3. Condenser clean and free of air obstruction.

4. High-pressure cutout shuts down the unit if the condenser pressure reaches 110 pounds.

> CAUTION: The high pressure cutout remakes contact automatically to start the purge unit on 75 lbs. single phase motors have a built-in thermal overload stopping the motor on overload. It automatically resets to start the motor in a few minutes.

If the normal delivery of refrigerant is interrupted, it is usually caused by a valve being closed or because the float valve is not operating. This malfunction is indicated by a liquid rise in the upper sight glass. Immediate action must be taken to correct this trouble. If the liquid is not visible in the lower sight glass, the float valve is failing to close properly.

Economizer

A complete description of the function of the economizer is given under the refrigeration cycle. It is located in the cooler shell at the opposite end from the compressor suction connection and above the tube bundle. (See figure 17.)This component pre-cools liquid refrigerant returning to the evaporator.

The economizer is a chamber with the necessary passages and float valves, connected by an internal conduit passing logitudinally through the cooler gas space to the compressor second stage inlet. This connection maintains a pressure in the economizer chamber that is intermediate (about 0 Psig between the cooler and condenser pressures) and carries away the vapors generated in the chamber. Before entering the conduit, the economizer vapors pass through eliminator baffles to extract any free liquid refrigerant and drain it back into the chamber.

There are two floats in separate chambers on the front end of the economizer The top or condenser float valve keeps the condenser drained of refrigerant and admits the refrigerant from the condenser into the economizer chamber. The bottom or economizer float valve returns the liquid to the cooler or evaporator.

Evaporator

The cooler or evaporator, (see figures 17, 18, and 19), is of a horizontal shell and tube construction with fixed tube sheets. The shell is low carbon steel plate rolled to shape and electrically welded in place.

The cooler and condenser both have corrosion-resistance cast iron water boxes. They are designed to permit complete inspection without breaking the main pipe joints. Full size separate cover plates give access to all tubes for easy cleaning. The cooler water boxes are designed for maximum 200 lbs working pressure. They are provided with cast iron division plates to give the required water pass flow.

Both the cooler and condenser have tube sheets of cupre-nickle, welded to the shell flange. Cupre-nickle is highly resistant to corrosion.

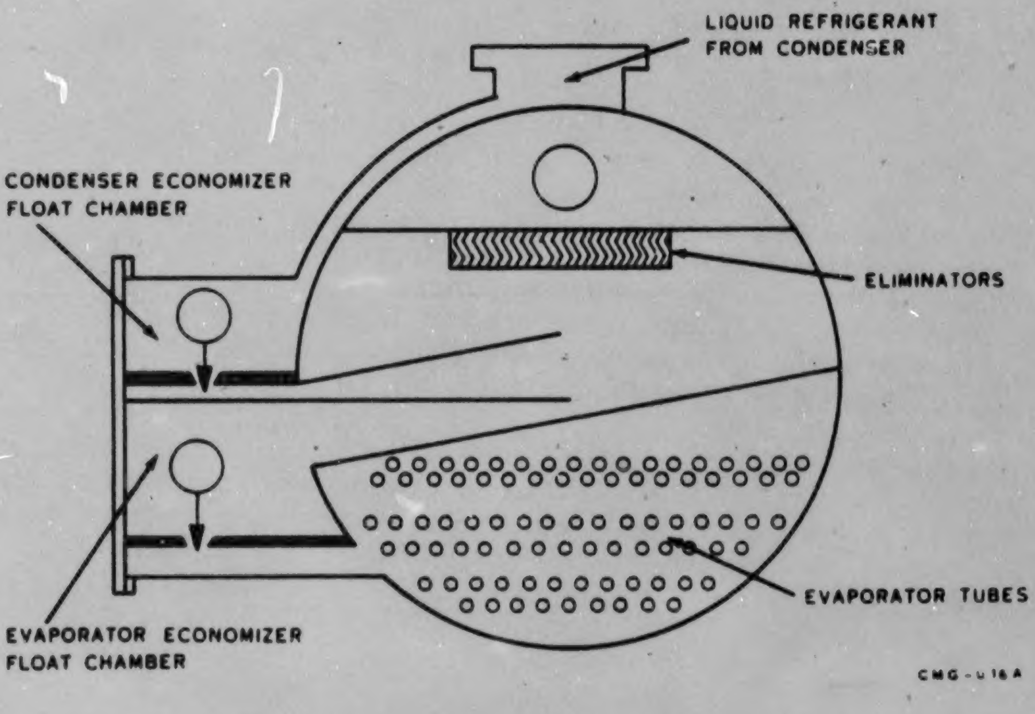

LIQUID REFRIGERANT FROM CONDENSER
CONDENSER ECONOMIZER FLOAT CHAMBER
ELIMINATORS
EVAPORATOR TUBES
EVAPORATOR ECONOMIZER FLOAT CHAMBER
CMG-U16A

Figure 17. Cross Section - Economizer

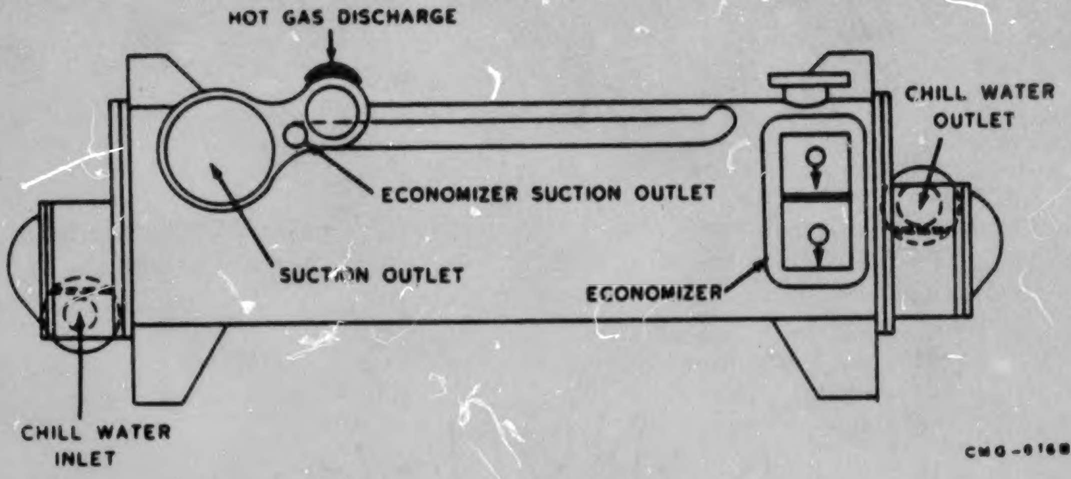

HOT GAS DISCHARGE
CHILL WATER OUTLET
ECONOMIZER SUCTION OUTLET
SUCTION OUTLET
ECONOMIZER
CHILL WATER INLET
CMG-616B

Figure 18. Evaporator Diagram

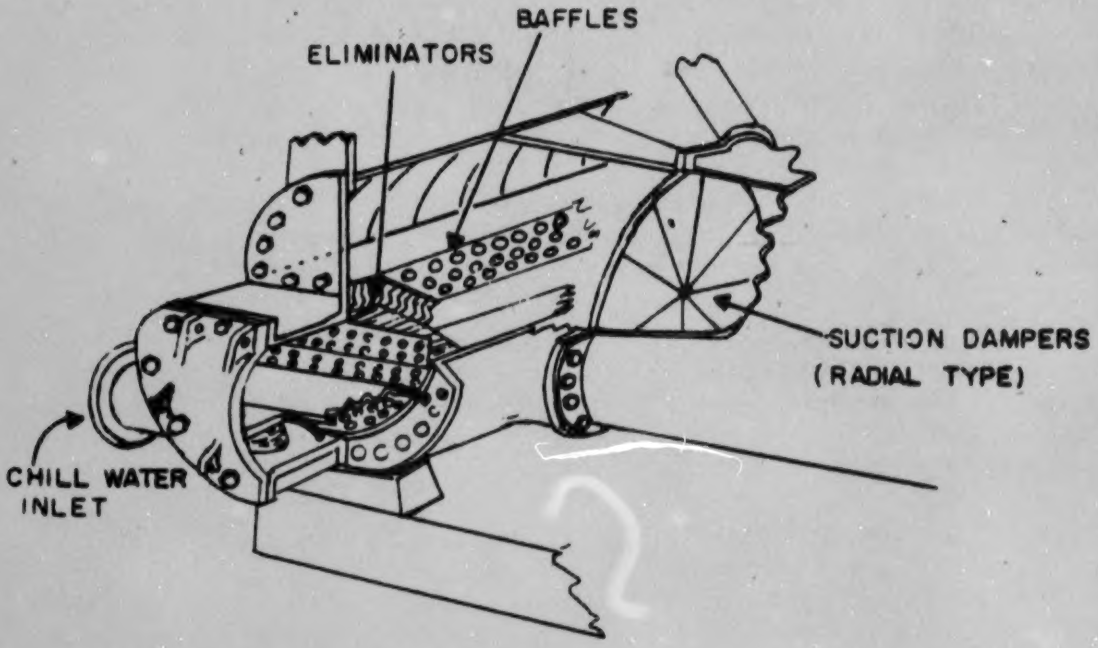

BAFFLES
ELIMINATORS
SUCTION DAMPERS
(RADIAL TYPE)
CHILL WATER
INLET

Figure 19. Cutaway Section - Suction End of Evaporator

The tubes in the cooler are copper tubes with an extended surface. The belled ends are rolled into concentric grooves in the holes of the tube sheets. Tube ends are rolled into the tube sheets and expanded into two internal support sheets. By this, the advantage of removable tubes is obtained.

The normal refrigerant charge in the cooler covers only about 50 percent of the tube bundle. However, during operation, the violent boiling of the refrigerant usually covers the tube bundle.

The cooler is equipped with multibend, nonferrous eliminator plates above the tube bundle which remove the liquid droplets from the vapor stream and prevent carryover of liquid refrigerant particles into the compressor suction. Inspection covers are provided in the ends of the cooler to permit access to the eliminators.

A rupture valve with a 15-lb bursting disc is provided on the cooler and a 15 Psig pop safety valve is screwed into a flange above the rupture disc. These items are strictly for possible disaster conditions because it is highly improbable that a pressure greater than 5 to 8 Psig will ever be attained without purposely blocking off the compressor suction opening.

An expansion thermometer is provided to indicate the temperature of the refrigerant within the cooler during operation. A sight glass is provided to observe the charging and operating refrigerant level.

A charging valve with connections is located on the side of the cooler for adding or removing refrigerant. The connection is piped to the bottom of the cooler so that complete drainage of refrigerant is possible. A refrigerant drain to the atmosphere is also provided near the charging connection expansion thermometer.

A small chamber is welded to the cooler shell at a point opposite the economizer and above the tube bundle. A continuous supply of liquid from the condenser float chamber is brought to the expansion chamber while the machine is running. The bulb of the refrigerant thermometer and the refrigerant safety thermostat bulb are inserted in this expansion chamber for measuring refrigerant temperature.

REFRIGERANT. Trichloromonofluoromethane, $CFCl_3$, (R-11), is a colorless liquid at normal atmospheric pressures and temperatures. It is very volatile and boils at 74.8°F. It may be handled in open containers with little loss by evaporation. The liquid is about 1.5 times as heavy as water and weighs 12-1/2 lbs per gallon. A mixture of water and liquid refrigerant will separate completely, the water floating above the heavier refrigerant. The liquid will dissolve oils and greases in all proportions. It dries the skin by removing the natural oils. It also dissolves rubber and will, therefore, destroy packing materials containing rubber.

The vapor is heavy - about 4.8 times as heavy as air. Being heavy, it will drop to the floor of a room and settle in low places. For this reason, openings in the top of chambers containing refrigerant vapor will cause little loss.

The odor of the vapor is sweet. Large concentrations in air are not harmful, but will cause dizziness and eventually headache.

The vapor will not support combustion and is classed as nonflammable and nontoxic.

The refrigerant is shipped in drums of 200 lbs net. The quantities for charging machines depend on the cooler size. The 100 ton centrifugal unit trainer holds a charge of 650 lbs.

Cooler and Condenser Check Points

The operator must check the cooler and condenser for proper refrigerant level and make sure that the tubes in the cooler and condenser are in efficient operating condition.

The correct refrigerant charging level is indicated by a cross wire on the sight glass. The machine must be shut down to get an accurate reading on the sight glass. For efficient operation, the refrigerant level must not be lower than 1/2 inch below the cross wire; a refrigerant level above this reference line indicates overcharge. When this condition exists, the overcharged refrigerant must be removed.

If the machine has been in operation for long periods of time, the refrigerant level will drop due to refrigerant loss. When this condition exists, additional refrigerant must be added to the system to bring the refrigerant level to its proper height as indicated on the cross wire. Observe all cautions and do not overcharge the cooler.

A method of determining if the tube bundle of either the cooler or condenser is operating efficiently is to observe the relation between the change in temperature of the condenser water or chilled water and the refrigerant temperature. In most cases, the chilled water or condenser water flow is held constant. Under such conditions, the temperature change of chilled water and condenser water is a direct indication of the load. As the load increases, the temperature difference between the leaving water or condenser water entering and the refrigerant increases.

A careful check should be made of the temperature differences at full load when the machine is first operated, and a comparison made from time to time during operation. During constant operation over long periods of time the cooler and condenser tubes may become dirty or scaled, and the temperature difference between leaving water or chilled water will increase. If the increase in temperature is approximately 2° to 3°F at full load, the tubes should be cleaned.

Read the condenser pressure gage when taking readings of the temperature difference between leaving condenser water and condensing temperature. Before taking readings, make sure the condenser is completely free of air. The purge unit should be operated for at least 24 hours before readings are taken.

Suction Damper

The suction damper, (figures 19 and 20), is a throttling damper built into the cooler suction flange located between the evaporator or cooler and the compressor. By throttling the compressor suction, the pressure differential through which the compressor must handle the refrigerant vapor, is increased. The centrifugal compressor has a very flat characteristic, i.e., the pressure differential against which it will deliver, is definitely limited by the speed at which it is running. Consequently, increasing the differential will result in a decrease in the amount of refrigerant pumped. It has already been stated under the heading "Centrifugal Compressor", that: At normal speeds, the unit is capable of producing a suction temperature about 60°F below the temperature of condensation; therefore, throttling of the suction of the compressor is a very effective method of capacity control.

Control Panel

The control panel, item 8 on figure 3, houses the suction, discharge, back of seal and seal chamber pressure gages; also, the high head pressure cutout, low oil pressure cutout, low chill water temperature cutout, and the low liquid refrigerant temperature cutout. This allows for a central and ready accessible location of these safety controls.

Refrigeration Cycle

The centrifugal refrigeration system employs the same general type of compression refrigeration cycle used on other mechanical refrigeration systems. Its features are as follows:

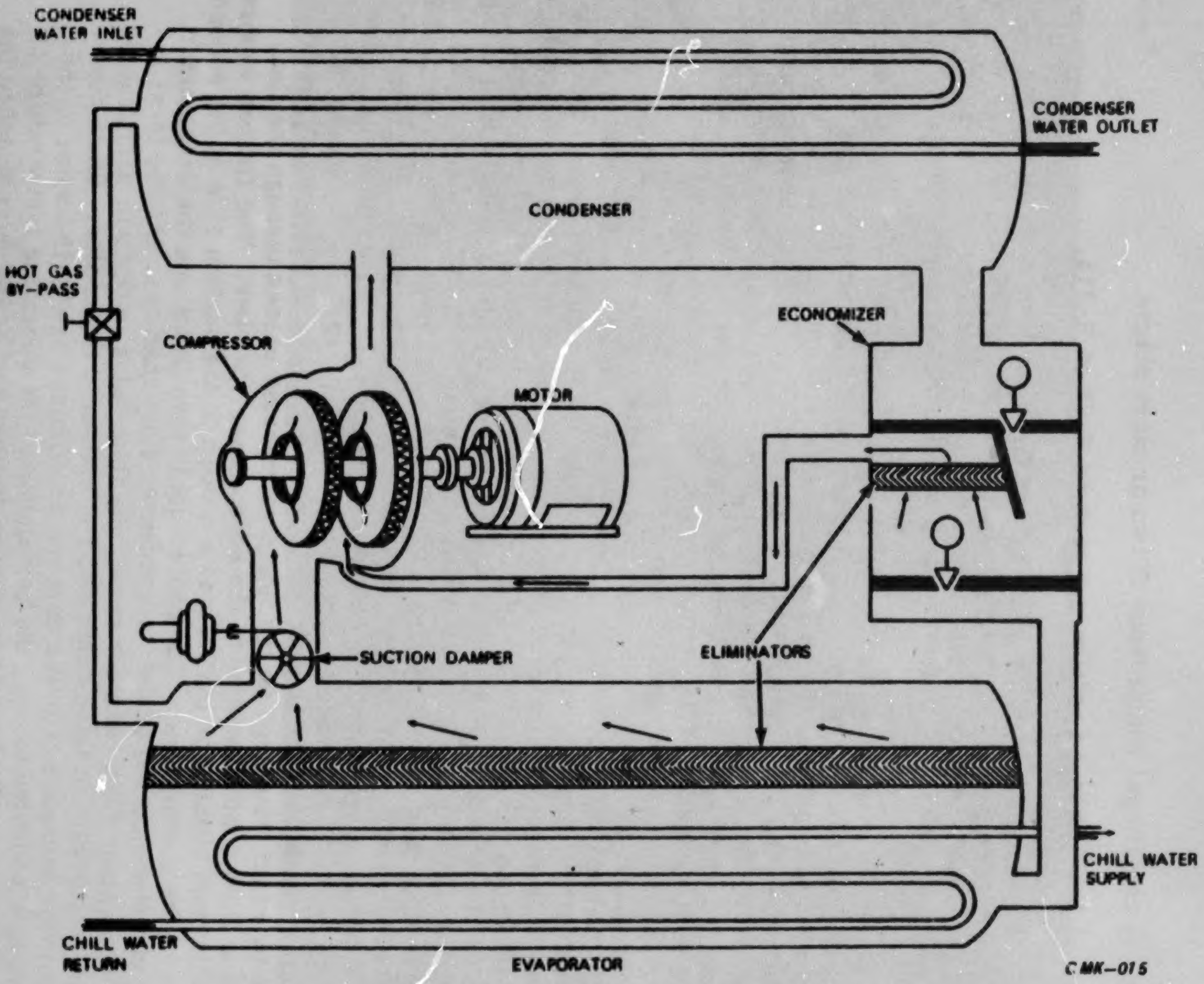

CONDENSER WATER INLET
CONDENSER WATER OUTLET
CONDENSER
HOT GAS BY-PASS
ECONOMIZER
COMPRESSOR
MOTOR
SUCTION DAMPER
ELIMINATORS
CHILL WATER SUPPLY
CHILL WATER RETURN
EVAPORATOR
CMK-015

Figure 20. Refrigeration Cycle

- A centrifugal compressor of two or more stages.
- A low-pressure refrigerant such as R-11 or R-113.
- An economizer in the liquid return from the condenser to the evaporator. The use of this piece of equipment reduces the horsepower required per ton of refrigeration by increasing the efficiency of the refrigeration cycle. It is made possible by using a multistage turbo-compressor.

The refrigerant cycle is more easily described by starting at the evaporator of the machine. (See figure 20.) Since the chilled water flowing through the tubes is warmer than the refrigerant in the shell surrounding the tubes, the heat flows from the chilled water to the refrigerant. This heat evaporates the refrigerant at a temperature corresponding to the evaporator pressure. Refrigerant vapors are drawn from the evaporator shell into the suction inlet of the compressor. The suction vapors are partially compressed by the first stage impeller and then combined in the flash gas vapors coming from the economizer at the second stage impeller inlet. (See figures 17, 18, and 20.) Refrigerant gas discharged by the compressor condenses on the outside of the condenser tubes by giving up heat through the condenser tubes to the cooler condenser water. The liquified refrigerant drains from the condenser shell down through an inside conduit into the condenser float chamber on the side and near the end of the evaporator shell. As the refrigerant level rises in the float chamber, the float valve is opened and allows the liquid to pass into the economizer chamber which is in the end of the cooler. The pressure in the economizer chamber is approximately halfway between the condensing and evaporating pressures; consequently, sufficiently warm liquid refrigerant evaporates to cool the remainder to a temperature (lower) corresponding to the lower pressure in the economizer chamber. This evaporation takes place by rapid "flashing" as the liquid refrigerant passes through the float valve and the conduit leading to the economizer chamber. The flashed vapors pass through eliminator baffles and a conduit to the suction side of the second stage of the compressor. The cooled liquid then flows into the economizer float chamber located below the condenser float chamber. As the level in the economizer float chamber rises, the float valve is opened, allowing the liquid refrigerant to flash again into the bottom of the cooler. Since the evaporator pressure is lower than the economizer pressure, some of the liquid is evaporated to cool the remainder to the operating temperature of the evaporator. These vapors pass up through the liquid refrigerant to the compressor suction. The remaining liquid serves as makeup for the refrigerant continually being evaporated by the chilled water. This completes the cycle.

SAFETY CONTROLS. Safety controls are provided to stop the centrifugal machine under any hazardous condition. The safety controls (see figure 21) are as follows:

1. Low oil pressure switch.
2. High condensing pressure cutout.
3. Low refrigerant temperature cutout.
4. Low chill water temperature cutout.
5. Chill water pump interlock.
6. Drum control interlock.
7. Thermal overload cutout.

Low oil pressure may cause damage to the bearings and to the seal. High condensing pressure may result in overloading of the compressor, gears or motor and damage to the condenser. Low refrigerant temperature and low water temperature may freeze the water in the cooler tubes and result in tube rupture. The chilled water pump interlock prevents the machine from continuing to run after the start button is released. Chilled water must be circulating through the cooler tubes to prevent the idle water from freezing. Therefore it is necessary to limit the operating pressures and temperatures. The drum control interlock prevents starting the motor unless all resistance is in the rotor circuit. The thermal overload cutout protects the control circuit.

SAFETY CONTROL OPERATION. All the safety controls are automatic reset instruments. Each safety instrument operates a relay switch which has one normally open and one normally closed contactor. The only safety controls not considered to be automatic reset instruments are the chill water pump and drum control interlocks. These are manual starting units. When a safety instrument is in a safe position, the corresponding relay is energized and current is passed through the closed contactor. Should an unsafe condition exist, a safety control will deenergize the corresponding relay and the normally closed contactor will open to energize the circuit breaker trip circuit. When the circuit breaker trip circuit is energized, the circuit breaker trips open and stops the compressor motor. The oil safety switch operates somewhat differently. Since the oil pressure is not up to design conditions until the compressor comes up to speed, the relay for the oil pressure switch must be by-passed when the machine is started. The function of by-passing the relay for the oil safety switch is accomplished by a time delay relay in the circuit breaker, which keeps the trip circuit open until the compressor is up to speed. After a predetermined time interval, the time delay relay closes the trip circuit at the circuit breaker and the oil safety switch serves its function. If the oil pressure does not build up by the time the time delay relay closes, the trip circuit will be energized and the machine will stop. The low oil pressure switch cuts out at five pounds and in at six pounds. The high condensing pressure cuts out at 12 psi and in at eight psi. The low refrigerant temperature cuts out at 32°F and in at approximately 35°F. The low chill water temperature cuts out at 38°F and in at 45°F.

OPERATIONAL CONTROLS. The operational controls are as follows:

1. Compressor speed control.
2. Chilled water control.
3. Condenser water temperature.
4. Hot gas by-pass.

Compressor speed control. When a compressor is driven by a variable speed wound rotor motor, motor speed, and therefore, compressor speed is controlled by varying the resistance in the rotor circuit of the motor by means of a "Drum Controller."

Suction Damper Control. Throttling the suction of the compressor is obtained by a throttling damper built into the evaporator suction flange. Suction damper modulation is effected by means of a temperature controller that sends an air signal to the suction damper motor in response to temperature changes of the chilled water leaving the cooler.

Condenser Water Temperature Control. By throttling the condenser water flow, the condenser pressure can be increased, thereby increasing the pressure differential on the compressor and reducing its capacity. Occasionally, the lowest speed available by means of the variable speed control furnished, may be insufficiently low to meet the operation conditions. In such a case, the condenser water flow may be throttled and the compressor speed requirement brought up into the range of the speed control.

Hot Gas By-pass Control. The hot gas bypass is used to prevent the compressor from surging at low load conditions. Should a low load condition exist, the hot gas by-pass hand valve is opened until surging stops. In reality, hot gas is by-passed directly from the condenser through a flange with a venturi (restrictor) using a small amount of liquid to desuperheat the gas. The precooled gas can then be injected into the cooler or evaporator. The hot gas supplements the small volume of gas that is evaporated in the cooler due to a low load condition. The head pressure is trying to return to the low side through the compressor backwards when the suction damper closes. This is when surging takes place.

ADJUSTMENT OF OPERATIONAL CONTROLS. The control system drawings give actual settings for pressure controllers. The final settings should be determined under actual operating conditions. You must determine what pressure change corresponds to a speed change and then adjust the pressure controller accordingly. Refer to the "Manufacturer's Guides or Manuals" on details of adjustments.

Capacity Controls

Listed below are the three methods of controlling the capacity output of a centrifugal machine.

1. Controlling the speed of the compressor.

2. Throttling the suction of the compressor.

3. Increasing the discharge pressure of the compressor.

The three methods given are listed in order of their efficiency. At partial loads, the power requirements will be least if the compressor speed is reduced - not quite as low if the suction is throttled - and highest if the condenser water flow is throttled to increase the discharge pressure. As you have probably already noticed, the operational controls and capacity controls are the same with exceptions to the hot gas by-pass. The hot gas by-pass is not a capacity control; it serves only to control surging at low loads thereby considered to be an operational control only.

Control Circuit

The control circuit in figure 21 uses 110 V a.c. as a power source. This control circuit is used to connect the various safety and operational control relays in such a manner as to allow current to flow through the circuit, thus protecting the system against hazardous conditions, and allowing the starting of the machine.

The thermal overload, low liquid refrigerant temperature cutout, low chill water temperature cutout, high head pressure cutout, and the stop button are normally closed. These relays will open, stopping the machine, whenever a hazardous condition exists. Since the stop button is a manual control, it must be depressed by the operator.

Before starting the system, the operator must manually close the chill water pump interlock and place the handle on the drum controller in the "off" position, closing the drum control interlock. To start the system, the operator must manually depress the start button, thus creating a circuit through the thermal overload, interlock control relay, low liquid refrigerant temperature cutout, low chilled water temperature cutout, high head pressure cutout, drum control interlock, the start button and the stop button.

Current will also flow through the chilled water pump interlock, and upon reaching the maximum oil pressure, the oil pressure switch will close. If after a twenty second period, the oil pressure switch has not closed, release the start button and check your electrical circuit for possible troubles.

After the oil pressure switch has closed, and after the drum controller is placed in speed "1" or higher, the current will flow through the following: thermal overload, interlock control relay, low liquid refrigerant temperature cutout, low chill water temperature cutout, high head pressure cutout, oil pressure switch, chilled water pump interlock and the stop button.

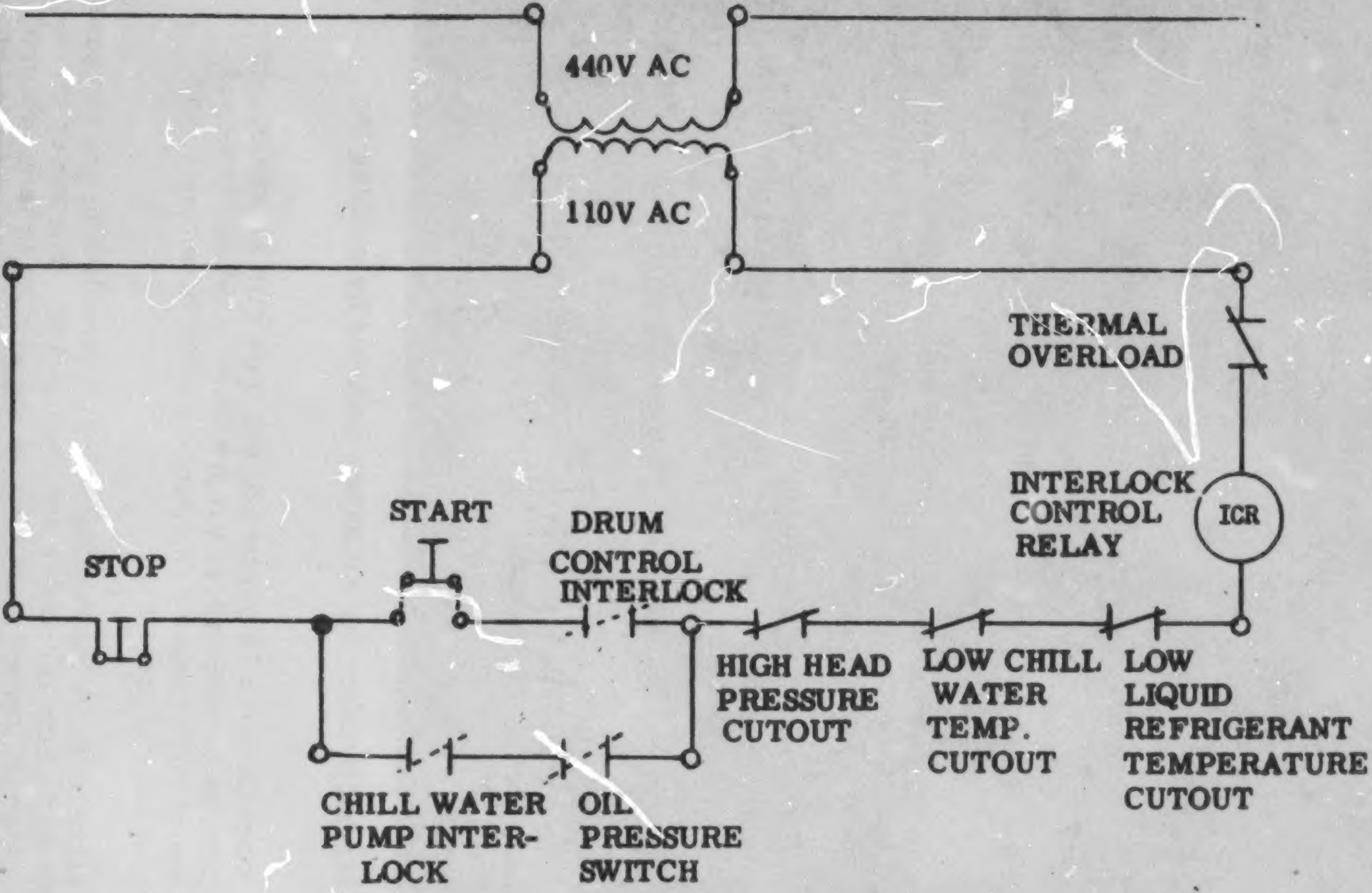
To stop the machine, whether normal or emergency operation, depress the stop button. NOTE: The interlock control relay is energized by a magnetic coil that closes and allows current to flow to the holding coil of the main circuit breaker trip switch. Should the power be interrupted by any of the safety controls, the ICR (interlock control relay) will deenergize, tripping the main circuit breaker trip switch.

SYSTEMS OPERATION

The centrifugal machine is stopped and started by the operating personnel. Definite operating instructions may be prepared by your installation supervisor, and are usually posted near the machine for ready reference.

It is very difficult to give definite instructions in this manual on the operation procedures for a given installation. Various design factors change the location of controls, types of controls used, and equipment location and will have a definite effect on operational procedures.

In this section, a general description of startup and shutdown instructions is given. It is recommended that you follow your installation standard operating procedure or operating instructions.


440V AC
110V AC
THERMAL OVERLOAD
INTERLOCK CONTROL RELAY
ICR
START
STOP
DRUM CONTROL INTERLOCK
HIGH HEAD PRESSURE CUTOUT
LOW CHILL WATER TEMP. CUTOUT
LOW LIQUID REFRIGERANT TEMPERATURE CUTOUT
CHILL WATER PUMP INTER-LOCK
OIL PRESSURE SWITCH

LEGEND: NORMALLY CLOSED SWITCHES

NORMALLY OPEN SWITCHES
(OR CLOSED MANUALLY)

Figure 21. Control Circuit

Normal Starting Procedures

Listed below are the recommended steps that can be used in normal starting:

1. Check oil levels for motor, gear, couplings, compressor, and bearing wells.

2. Allow condenser water to circulate through the condenser, being sure to vent air and allow the water to flow through slowly. This precaution must be observed to avoid water hammer.

3. Allow chilled water to circulate through the cooler. Be sure to vent the air and allow the liquid to flow through slowly. As explained above, this will help in preventing water hammer.

4. Make sure that air pressure is present at all air-operated controls.

5. Start the purge unit before starting the machine; this helps in removing air from the machine. The purge recovery unit should be operated at all times while the machine is operating.

6. Make sure all safety controls have been reset and that the control lever is in "OFF" position.

7. Close the circuit breaker for all safety controls by pushing the start button in.

8. Bring the machine up to 75 percent of full load with all resistance in. Check oil gages to make sure proper oil pressure is being developed. If proper oil pressure is not developed in approximately 20 seconds, the machine will cutout on low oil pressure.

9. Open the valve to allow the cooling water to circulate to the compressor oil cooler, gear or turbine oil cooler and seal jacket. The water circulating to the compressor oil cooler must be kept low enough in temperature to prevent the highest bearing temperature from exceeing a temperature of 180° F. The seal bearing temperature should run approximately 160°F, while the thrust bearing temperature runs at approximately 145° F under normal operating conditions. These temperatures should be checked closely until they maintain a satisfactory point.

10. After starting, the machine may surge until the air in the condenser has been removed. During this surging period, the machine should be

run at high speed; this helps the process of purging. The condenser pressure should not exceed 12Psig and the input current to motor-driven machines should not run over 100 percent of the full load motor rating. The machine will steady itself out as all the air has been purged. After leveling out the motor speed, the damper may be adjusted to give the desired coolant temperature. The motor should be increased slowly, point to point. Do not proceed to the next speed point until the motor has obtained a steady speed. Keep a close observation on the ammeter to make sure that the motor does not become overloaded.

Normal and Emergency Shutdown

NOTE: Normal and emergency shutdown procedures are performed in the same manner.

The following steps are used in shutting down the centrifugal machine.

1. Stop the motor by depressing the stop button.

2. After the machine has stopped, turn off the water valve which supplies water to the compressor oil, gear oil cooler, and the seal housing.

3. Shut down all pumps as required.

Shutdown periods may be broken down into two classes, standby and extended shutdown. Standby shutdown may be defined as the period of time during which the machine must be available for immediate use, while extended shutdown is defined as that period of time during which the machine is out of service.

STANDBY SHUTDOWN. The following checks must be made during standby shutdown and corrective action taken.

1. Maintain proper oil level in the oil reservoir and in the suction damper stuffing box.

2. Room temperature must be above freezing.

3. Machine must be kept free of leaks.

4. Purge unit must be operated as necessary to keep the machine pressure below atmospheric pressure.

5. If the machine pressure builds up in the unit due to room temperature rather than leakage of air into the machine, a small quantity of water

circulated through the condenser or cooler will hold the machine pressure below atmospheric. Periodic operation of the purge unit will accomplish the same result.

6. The machine should be operated a few minutes each week to circulate oil and lower the refrigerant temperature.

EXTENDED SHUTDOWN. If the system is free of leaks and the purge unit holds down the machine pressure, the following instructions and corrective actions must be taken in long shutdown periods.

1. Drain all water from the compressor, gear and turbine oil cooler, condenser, cooler, seal jacket, pumps, and piping if freezing temperatures are likely to develop in the machine room.

2. It is possible for the oil to become excessively diluted with refrigerant causing the oil level in the pump chamber to rise. This level should not be allowed to rise into the gear bearing chamber; if this occurs, remove the entire charge of oil.

LOGS AND RECORDS

A daily operating log is maintained at each attended plant for a record of observed temperature readings, water flow, maintenance performed, and any unusual condition occurring which affects an installation operation. The operator is held responsible for keeping an accurate log while on duty.

A master chart of maintenance duties, each component identified, is usually prepared by the installation supervisor and includes daily, weekly, and monthly maintenance services. The maintenance items included on the chart are applicable to a specific installation. The items on the chart must be checked accordingly.

The master chart is placed near the operating equipment for ready reference so that operators can identify the specific maintenance service required.

The supervisor schedules operator maintenance duties which are selected from the master chart. Each operator, while on duty, must perform the outlined job and enter his progress in the daily log.

A good log will help the operator locate troubles rapidly. A typical log sheet has spaces for all important entries and a carefully kept log will help make troubleshooting easier.

Charging the Unit

The manufacturer usually ships the refrigerant in large metal drums. These drums weigh approximately 200 pounds. At temperatures above 74.8°F, the drum will be under pressure. To prevent loss of refrigerant or injury, never open the drums to atmosphere when above this temperature. It is possible to charge refrigerant from an open drum at 60°F temperature, although it is recommended that leak-tight connections be made to the charging valve. The charging valve is located on the side of the cooler. To help in the charging procedure, each refrigerant drum has a special type of plug installed on the side of the drum. This plug is specifically engineered for charging purposes. The charging connection on the drum consists of a two-inch plug in which is inserted a smaller 3/4-inch plug. The 3/4-inch opening inside the drum is covered with a friction cap. The cap prevents leakage into or out of the drum when the 3/4-inch plug is unscrewed. To charge the machine with refrigerant, proceed as follows:

1. The machine must be under a vacuum.
2. Install a 3/4-inch nipple into the standard globe valve and close the valve.
3. Remove the 3/4 inch plug inserted in the two-inch plug from the drum.
4. Place the valve with the nipple into the opening, making sure that it is far enough in to push off the cap inside the drum.
5. Place the drum in a horizontal position near the cooler charging valve with the use of a hoist. The drum should be high enough to allow the refrigerant to flow as a liquid, by gravity, from the drum to the charging line. Rotate the drum so that the valve is at the bottom.
6. Connect the two valves (drum and cooler) with a copper tube and fittings making sure all the joints are leakproof.
7. Open both valves and allow the refrigerant to flow into the cooler. Operate the machine to maintain a vacuum after the initial reduction to zero.
8. When the drum is empty, close the valve on the cooler and disconnect the drum. Remove the valve for use with the next drum. Complete charging of the machine requires 650 pounds of R-11.

ADDING REFRIGERANT TO MAINTAIN A STANDARD LEVEL. When adding refrigerant, use the same procedures as explained above. Another method that can be used to add refrigerant is to simply allow the refrigerant to be drawn in as a gas. This can be done by letting the drum rest on the floor and letting the gas escape into the cooler while the machine is in operation or idle.

Removing Refrigerant Charge

In removing refrigerant from the cooler, the following procedure is recommended.

1. Inject air into the machine until a pressure of two to five pounds gage is reached by use of the purge recovery unit.
2. Connect tubing to the charging valve on the cooler and allow the refrigerant to discharge into the refrigerant drum.
3. Less loss of refrigerant will take place if the refrigerant is cold. Always allow space in the drum for refrigerant expansion.

Oil Replacement

1. Gage pressure in the machine should run approximately 1 psig.
2. Drain oil from the bottom of the main oil reservoir cover.
3. Remove the main oil reservoir cover and clean the chamber to remove all impurities.
4. Replace the main oil reservoir cover.
5. Remove access bearing cover plate.
6. Lift up the shaft bearing caps by reaching through the bearing access hole and removing the two large capscrews.
7. Fill the bearing approximately 3/4 of the full charge allowing the excess oil to flow into the main oil reservoir.
8. Replace the bearing cap and secure with capscrews.
9. Remove the brass plug from the thrust housing and remove the strainer; clean and replace.
10. Replace the plug and secure.
11. Drain oil through the plug in back of the seal oil reservoir.
12. Remove the cover from the seal oil reservoir.
13. Remove filter from left-hand chamber, discard, and replace with new filter.
14. Refill the reservoir with new oil.
15. Replace the cover and secure nuts evenly and tightly.
16. Drain the oil through the plug at the bottom of the oil reservoir that is vented to the atmosphere.
17. Remove the oil fitting plug in the atmospheric oil reservoir and pour fresh oil until the level is halfway in the atmospheric float chamber sight glass.
18. Replace the plug and secure handtight.
19. Operate the purge unit to remove as much air as possible before starting the machine.
20. Add oil to the atmospheric float chamber, if main oil reservoir indicates undercharge after a short period of operation.

MAINTENANCE CHECKLIST

The following checklist should be used in inspecting the many components of the centrifugal machine. Maintenance problems will be greatly reduced by using the following schedule. This scheduled is outlined in AFM 85-18.

	Inspection Interval									
	Hourly	Daily	Weekly	Monthly	Quarterly	Twice Yearly	Yearly	Running	Stopped	Remarks
COMPRESSOR										
1. Review operating log				x						
2. Complete oil change							x		x	
3. Check oil filter pressure drop		x								
4. Renew seal oil filter					x			x		2
5. Clean thrust oil strainer							x		x	
6. Check oil pump drive							x		x	
7. Check oil heater and flow switch			x					x	x	
8. Oil level in pump chamber	x							x	x	
9. Oil level atmospheric chamber	x							x	x	
10. Oil level seal oil reservoir		x							x	
11. Oil pressure seal chamber	x							x		
12. Oil pressure back of seal	x							x		
13. Shaft bearing temperatures	x							x		
14. Inspect seal									x	1

		Inspection Interval									
		Hourly	Daily	Weekly	Monthly	Quarterly	Twice Yearly	Yearly	Running	Stopped	Remarks
15.	Shaft bearing clearances							x		x	
16.	Shaft labyrinth clearances									x	1
17.	Thrust bearing							x		x	
18.	Oil cooler - water leak										1
19.	Oil safety cutout - in				x				x		
20.	High pressure safety cutout				x				x		
21.	Water to seal water jacket	x							x		
22.	Water to oil cooler	x							x		
23.	Seal opening clearance							x		x	

NOTE:
1. Perform inspections and tests as found necessary
2. As often as required.
3. Add oil when idle.

COOLER

		Hourly	Daily	Weekly	Monthly	Quarterly	Twice Yearly	Yearly	Running	Stopped	Remarks
1.	Review operating logs				x						
2.	Refrigerant level - machine idle				X					x	
3.	Refrigerant temperature - machine running	x							x		
4.	Check for fouled tubes							x	x	x	1
5.	Refrigerant contamination									x	1

	Inspection Interval									
	Hourly	Daily	Weekly	Monthly	Quarterly	Twice Yearly	Yearly	Running	Stopped	Remarks
6. Low temperature refrigerant cutout				x				x		
7. Low water temperature cutout				x				x		
8. Condition of insulation										1
9. Leak test - low side						x			x	1
10. Seal on suction damper		x						x	x	
11. Rupture valve						x			x	
CONDENSER										
1. Review operating logs				x						
2. Check for fouled tubes							x	x	x	1
3. Leak test high side				x				x		
4. Check for air and noncondensable gases		x						x		
PURGE RECOVERY UNIT										
1. Compressor oil change						x			x	
2. Oil level	x							x		
3. Refrigerant level in separation chamber		x						x		
4. Pressurestat cutout						x		x		
5. Relief valve setting				x				x		
6. Regulating valve operation		x						x		
7. Suction - discharge pressure	x							x		

		Inspection Interval									
		Hourly	Daily	Weekly	Monthly	Quarterly	Twice Yearly	Yearly	Running	Stopped	Remarks
8.	Water Collection		x						x		
9.	Excessive purging	x							x		
10.	Motor lubrication - cleanliness				x					x	
11.	Belts-condition-alignment					x			x		
12.	Compressor efficiency				x			x			
13.	Clean condenser				x					x	
14.	Oil separator float					x			x		
15.	Pressure test			x				x	x		

NOTE:
1. Perform inspections and tests as found necessary.
2. As often as required.
3. Add oil when idle.

GEAR

		Hourly	Daily	Weekly	Monthly	Quarterly	Twice Yearly	Yearly	Running	Stopped	Remarks
1.	Oil level		x						x		
2.	Oil pressure	x							x		
3.	Clean oil strainer					x				x	1
4.	Condition of teeth and bearings							x		x	1
5.	Operating temperature	x							x		
6.	Water to oil cooler	x							x		
7.	Change oil							x		x	1

	Inspection Interval									
	Hourly	Daily	Weekly	Monthly	Quarterly	Twice Yearly	Yearly	Running	Stopped	Remarks
COUPLINGS										
1. Check lubrication			x						x	
2. Clean - renew lubricant						x			x	
3. Check alignment and wear							x		x	
MOTOR - CONTROLLER										
1. Bearing oil level		x						x	x	3
2. Collector rings and brushes						x			x	
3. Bearing condition									x	1
4. Bearing oil change						x			x	1
5. Condition of contacts					x				x	

NOTE:

1. **Perform inspections and tests as found necessary**
2. **As often as required.**
3. **Add oil when idle.**

TROUBLE DIAGNOSIS CHART

The steps to be taken in detecting and correcting operation of the centrifugal machine are outlined in the following trouble diagnosis chart. Use the proper methods for making these service adjustments, repairs, and corrections as outlined in this chapter.

All settings, clearances, and adjustments must be made to the manufacturer's specifications. The manufacturer's maintenance catalog gives definite clearances, temperatures, pressures, and positions for adjustment of component parts. These tolerances must be set as recommended for efficient operation; carelessness in these settings can cause extensive damage to the machine.

TROUBLE	PROBABLE CAUSE	REMEDY
High head pressure	Low on condenser water	Check condenser water pump for proper operation.
	Sealed and dirty condenser tubes	Inspect and clean condenser tubes.
	Division plate rupture	Remove air from lines
	Air in condenser. (Check differences between leaving water temperature and condensing temperature	Operate purge unit; find and repair leak.
	Condenser float valve in economizer stuck closed	Adjust float, examine valve seat, and eliminate cause of sticking.
	Condenser not transferring enough heat	Check items listed in (high condenser pressure)
Loss of capacity	Hot gas bypass valve open	Close valve.
	Gradual contamination of refrigerant by oil	Replace refrigerant charge.

Trouble	Probable Cause	Remedy
	Sudden increase in difference between refrigerant and water temperature	Check division plates and gaskets in cooler water box for breakage.
	Gradual increase in water and refrigerant temperature	Clean cooler tubes; remove excess oil from refrigerant check division plates and gaskets.
Compressor surges	Load too light	Open hot gas by-pass
	Air leak	Run purge unit and repair leak
	High condenser pressure	Check items listed in "high head pressure"
Refrigerant (R-11) too low	Charge lost or trapped in condenser or economizer by sticking floats	Find leak, check floats, add refrigerant after determining cause of leak.
	Purge unit leaking	Check relief valve.
Compressor second stage frosts	Evaporator float valve stuck closed in economizer.	Check float operation.
	Light load with cold condenser	Decrease flow of condenser water.
	Suction damper closure causes circulation of condensate from economizer	Readjust suction damper controls to give greater opening of damper.
Low-back of seal pressure with high seal pressure	Dirty filter	Remove, inspect and clean filter
	Filter cartridge improperly installed	Check installation of filter and replace correctly.
Compressor bearing too high	Insufficient flow of cooling water throughout oil cooler	Open throttling cock to oil cooler.
	Excessive dilution of oil by the refrigerant upon start up or electric oil heater off during shut down	Operate electric oil heater during shut down

Trouble	Probable Cause	Remedy
Compressor bearing too high	Temperature in pump chamber above 150°F when compressor is started	Turn on cooling water sooner on starting, check for clogged cooling coil. Check and clean.
	Thrust or shaft bearing scored	Check bearing and shaft end clearance.
Gear overheated	High oil level	Drain excess oil.
	Dirty cooler	Clean cooler tubes.
	Low cooling water flow	Increase cooling water flow.

SUMMARY

Direct expansion refrigeration systems pump refrigerant directly through the cooling coil, whereas indirect systems pump chill water or brine through the cooling coil. Indirect refrigeration may be either of the centrifugal or reciprocating type.

The graphic control panels are a schematic of the systems they monitor. Instruments and controls are located throughout the schematic which monitor and control the different systems. Individual units may be manually operated by an operator at the control panel.

There are several companies that manufacture the centrifugal machine. Except for a few engineering differences, these machines are the same. When in doubt about any maintenance or operational procedure, refer to the manufacturer's manuals or handbooks for specific information.

An itemized check list and operational log must be used and maintained by the operator on duty. Careful inspections will help in correcting malfunctions and give the machine long life and efficient operation.

QUESTIONS FOR STUDY GUIDE
BLOCK VIII Wk 3

1. An equipment cooling system using a secondary refrigerant is called what?
2. What will aid in sealing a condensate pan from rust and corrosion?
3. What type brush should be used to clean tubes in the condenser and cooler?
4. What is used to lubricate the drum control points?
5. What type oil is used in the centrifugal compressor?
6. What assures oil to the shaft bearings during startup?
7. How often should the oil be changed in the compressor?
8. What is the purpose of the baffle in the condenser?
9. What is the maximum RPM of the drive motor?
10. What type couplings are generally used on the centrifugal type units?
11. What is the primary purpose of the purge unit?
12. What is the purpose of the pressure reducing valve on the purge unit?
13. The pressure reducing valve and the automatic relief valve are set according to what temperature?
14. What should be done if the water collection is as much as one-half pint per day?
15. Does the purge unit use the same type oil as the centrifugal?
16. Where does the flash gas from the economizer enter the compressor?
17. What safety control is bypassed during startup?
18. What is the most efficient means of capacity control on the centrifugal machine?
19. During shutdown, what should be done to maintain the unit below atmospheric pressure?
20. A maintenance schedule for the centrifugal unit is found in what Air Force publication?
21. The air handler supplies an airflow of approximately what CFM?
22. What is the approximate pressure between the condenser and evaporator economizer float chambers?

23. What is the function of the eliminators in the evaporator?

24. The high pressure output on the centrifugal compressor is set for what PSI?

25. The brine solution is approximately what temperature?

26. The air leaving the preconditioner should be what temperature and humidity?

27. The component of the purge unit that separates water from the refrigerant is

the ____.

28. The steam coil in the preconditioner prevents outside air from entering below what temperature?

29. Which safety control must be manually opened?

30. During pressurization, a temporary connection is made on the purge unit between which two lines?

31. What is the range of operation of the suction damper?

32. What is the purpose of the vent valve on the seal chamber reservoir?

33. What does a flicker on the back of seal oil pressure gage indicate?

34. What position does the drum control interlock assume at speed 1 and higher?

References

1. AFM 85-18, Maintenance and Operation of Refrigeration, Air Conditioning and Evaporative Cooling, and Mechanical Ventilating Systems.

2. Textbook, Air Conditioning, Delmar.

3. Textbook, Modern Refrigeration and Air Conditioning, Althouse, Turnquist, and Bracciano.

WORKBOOKS 3ABR54530-VIII-9-P1 thru P11

Department of Civil Engineering Training

Refrigeration and Air-Conditioning Specialist

INDIRECT EXPANSION AIR-CONDITIONING SYSTEM

April 1975

SHEPPARD AIR FORCE BASE

11-8

Designed For ATC Course Use

DO NOT USE ON THE JOB

PURPOSE OF STUDY GUIDES, WORKBOOKS, PROGRAMMED TEXTS AND HANDOUTS

Study Guides, Workbooks, Programmed Texts and Handouts are training publications authorized by Air Training Command (ATC) for student use in ATC courses.

The STUDY GUIDE (SG) presents the information you need to complete the unit of instruction, or makes assignments for you to read in other publications which contain the required information.

The WORKBOOK (WB) contains work procedures designed to help you achieve the learning objectives of the unit of instruction. Knowledge acquired from using the study guide will help you perform the missions or exercises, solve the problems, or answer questions presented in the workbook.

The STUDY GUIDE AND WORKBOOK (SW) contains both SG and WB material under one cover. The two training publications are combined when the WB is not designed for you to write in, or when both SG and WB are issued for you to keep.

The PROGRAMMED TEXT (PT) presents information in planned steps with provisions for you to actively respond to each step. You are given immediate knowledge of the correctness of each response. PTs may either replace or augment SGs and WBs.

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1B- 75-1270

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This supersedes SG 3ABR54530-VIII-9, and WB 3ABR54530-VIII-9-P1 thru P11, August 1973.
Previous editions may be used.

USING PSYCHROMETRIC CHART TO DETERMINE THE PROPERTIES OF MIXED AIR

OBJECTIVE

When you have completed this workbook, you will be able to determine the properties of an air mixture within (±) 2% accuracy.

PROCEDURES

Using the diagram below and psychrometric chart provided by the instructor, plot the conditions of this system and answer the questions.

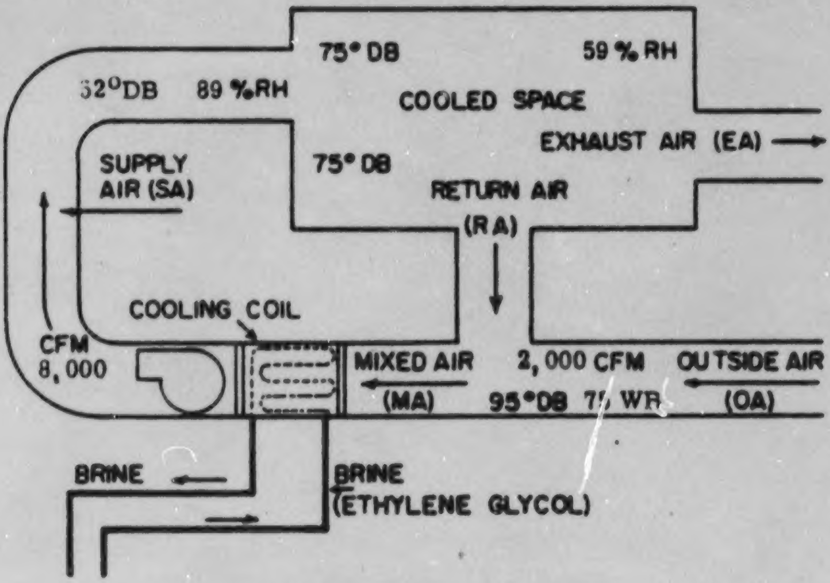
75° DB
59 % RH
52°DB
89 % RH
COOLED SPACE
EXHAUST AIR (EA)
SUPPLY AIR (SA)
75° DB
RETURN AIR (RA)
COOLING COIL
CFM 8,000
MIXED AIR (MA)
2,000 CFM
95°DB 75 WB
OUTSIDE AIR (OA)
BRINE
BRINE (ETHYLENE GLYCOL)

Figure 1. Mixed Air System

a. How many grains of moisture were removed from the mixed air?

b. Explain why the relative humidity increased AFTER it was cooled?

c. By adding the outside air to the return air, grains of moisture increased

________________________GM.

d. Under coil conditions, how much heat was removed?

e. Return air CFM is ___________.

f. The room load is __________ tons and the coil load is ______________ tons.

g. What is the percent of outside air?

h. What is the apparatus dewpoint of this system?

i. Supply air is also known as air ___________ the coil, and return air is known as air _______________ the coil.

j. How much does one cubic foot of supply air weigh?

WB 3ABR54530-VIII-9-P2
April 1975

OPERATION AND MAINTENANCE OF FRESH AIR AND RECIRCULATING AIR SYSTEMS

OBJECTIVE

When you have correctly answered all the questions in this workbook, you will be able to identify major components of the fresh air and recirculating air systems, their purpose, and maintenance procedures.

PROCEDURES

Using the study guide and instructions given to you by your instructor, research and answer the following questions.

1. Air Handlers.

a. Purpose ______________________________

____

b. What checks should be made after it has been installed?

(1) ______________________________

(2) ______________________________

(3) ______________________________

c. Why should these checks be made? ______________________________

____

2. Fan.

a. Purpose ______________________________

b. Types of Blower ______________________________

c. Types of Blower Drive ______________________________

____

3. Cooling Coil.

a. Purpose ______________________________

b. Types

(1) ______________________________

(2) ______________________________

4. Preheat and Reheat Coils.

   a. Purpose____

   ____

   b. Where would the preheat coil be located in the air handler?

   ____

   c. Why at this point in the system?________________________

   ____

   d. List the functions of the reheat coil. ______________________

   ____

   e. Where would the reheat coil be located in the air handler?

   ____

5. Filters.

   a. List the types of filters that can be used.

   (1)____

   (2)____

   (3)____

6. Air Wash.

   a. Purpose____

   ____

7. Dampers.

   a. Purpose____

   b. Types____

8. Two main points to consider in maintenance of air handlers are

   a.____

   b.____

9. List the items to be inspected on the air handler.

a. ______________________________

b. ______________________________

c. ______________________________

d. ______________________________

e. ______________________________

f. ______________________________

10. Belts.

a. Why should belts be inspected after 3 months or every 1,000 hours of operation? ______________________________

____

b. List the steps in removing and replacing multiple belts.

(1) ______________________________

(2) ______________________________

(3) ______________________________

(4) ______________________________

(5) ______________________________

c. Improper belt tension will cause

(1) ______________________________

(2) ______________________________

(3) ______________________________

(4) ______________________________

(5) ______________________________

(6) ______________________________

11. List the procedures in lubricating motor bearings.

a. ____

b. ____

c. ____

d. ____

OPERATION, MAINTENANCE AND FLOW OF SECONDARY REFRIGERANTS

OBJECTIVE

Using the workbook and 100-ton trainer, identify operation and maintenance procedures and trace flow of liquid circulating units through the system with no errors.

Part 1

PROCEDURES

Using the diagram, colored pencils and instructions from your instructor, perform the following tasks using the color codes listed below and then answer the questions from information provided in the study guide.

1. Start at the outlet of the condenser and trace the flow of condenser water through the system.
2. Start at the outlet of the evaporator and trace the flow of chilled water through the system.
3. Start at the evaporator of the brine chiller and trace the flow of brine through the system.

COLOR CODES

1. Condenser water = light green
2. Chilled water = dark blue
3. Brine = dark green

QUESTIONS

1. What are the liquid circulating units in the centrifugal system that are considered to be closed circuits? ____

   ____

2. What liquid circulating unit in the centrifugal system is considered to be an open circuit? ____

3. Why must the brine coils be downstream from the chilled water coils?

   ____

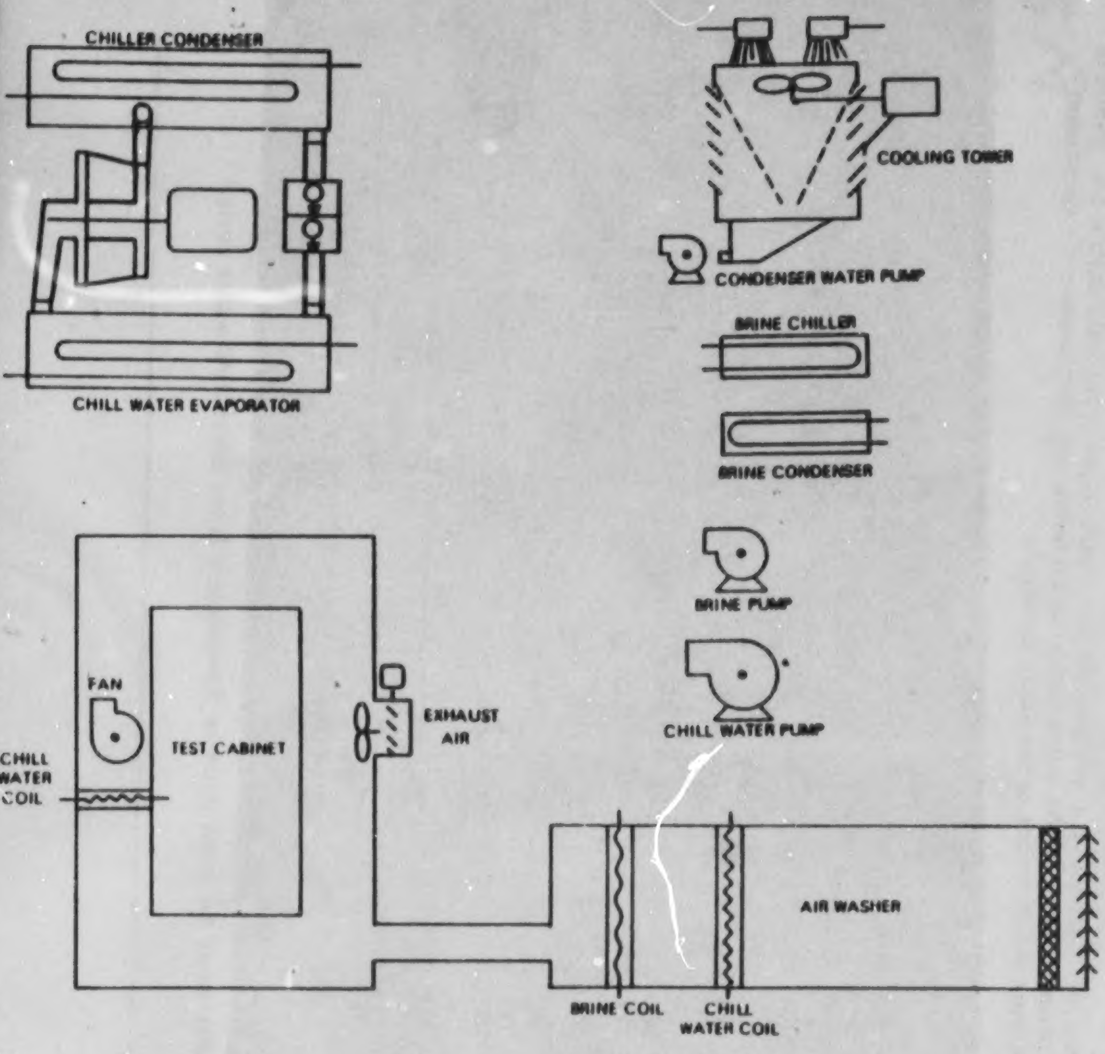
CHILLER CONDENSER
CHILL WATER EVAPORATOR
COOLING TOWER
CONDENSER WATER PUMP
BRINE CHILLER
BRINE CONDENSER
BRINE PUMP
CHILL WATER PUMP
FAN
TEST CABINET
CHILL WATER COIL
EXHAUST AIR
AIR WASHER
BRINE COIL
CHILL WATER COIL

Figure 2. Liquid Flow System

4. Where does chilled water enter the centrifugal evaporator? ____________________

____

Why? ____

5. In the test cabinet as outlined in figure 2, what is the purpose of the chilled water?

____

6. At what point in the centrifugal unit condenser, must condenser water enter first?

______________________________ Why? ______________________________

7. Describe in your own words the flow of liquid and gas refrigerant through the centrifugal machine. ____

____

____

8. What is the purpose of brine in the centrifugal system?

____

Checked by ______________________
(Instructor)

Part 2

PROCEDURES

Using the study guide, research and answer following questions.

1. Maintenance of secondary refrigerant systems.

   a. Check and brush cooler tubes at least ______________________

   b. Check difference between ____________ chilled temperature and ____________ temperature.

   c. Cleaning of tubes is required when ______________________

   d. Check refrigerant level at least ______________________

2. Maintenance procedures for cooler tube cleaning.

   a. Shut off the ____________________ and ____________________ valves.

   b. Drain water from the cooler through the ______________________________

   ____

   c. Remove all nuts from the water box covers leaving ____________________

   ____

   d. Using ____________________ provided, force the covers away from the flanges.

   e. Why must all gasket material be removed at this time?

   ____

   f. Remove the water box division plate at this time. If it is rusted in place, use ____

   g. Caution must be used because the division plate is made of ______________

   h. What type of brush is recommended for scrubbing the tubes?

   i. Why must this cleaning be done as quickly as possible?

   j. Replace the division plate after ______________________________

   ____

   k. Applying graphite to both sides of the water box cover gasket does what?

   ____

   l. What is the caution that must be observed at this time?

   m. Why must all bolts be tightened evenly?

   n. Close ____________ and ________________________ valves.

   o. How can the system be checked for leaktight joints?

3. Repair of cooler.

   No repair other than retubing is normally done and this requires a high degree of skill and will normally be done by contract.

WB 3ABR54530-VIII-9-P4
April 1975

IDENTIFICATION AND FUNCTION OF MAJOR COMPONENTS OF CENTRIFUGAL REFRIGERATION MACHINE

OBJECTIVE

Using centrifugal refrigeration machine trainer and Study Guide 3ABR54530-VIII-9, locate the following components and answer questions explaining their functions with no more than two (2) errors.

PROCEDURES

Locate the following components on the machine and explain their function.

1. Drum Controller
   a. Purpose ____________________
   b. What position must the drum controller be in at the start of the unit? __________
   Why? ____________________
2. Motor
   a. Voltage __________ ____________________
   b. Amperage ____________________
   c. Phase ____________________
   d. Horsepower ____________________
3. Speed Increaser
   a. Purpose ____________________
   b. Gear Speed ____________________
   c. Pinion Speed ____________________
4. Compressor
   a. Type ____________________
   b. Number of Stages ____________________
   c. Purpose ____________________

5. Condenser

a. Purpose ______________________________

b. Inlet location ______________, Water temperature ______________ F.

c. Outlet location ______________, Water temperature ______________ F.

d. Condenser temperature ______________________ F.

6. Economizer

a. Purpose ______________________________

b. Upper chamber pressure (approx.) ______________________ psi.

c. Lower chamber pressure (approx.) ______________________ psi.

d. How is the lower chamber pressure obtained? ______________________

____

7. Evaporator

a. Purpose ______________________________

b. Inlet location ______________ Water temperature ______________ F.

c. Outlet location ______________ Water temperature ______________ F.

d. Refrigerant temperature ______________________ F.

e. Refrigerant level ______________________________

8. Suction Damper

a. Purpose ______________________________

b. What type is on this unit? ______________________

c. How is the damper controlled? ______________________

d. What is the full movement of the damper? ______________________

____

9. Air Handler

a. Purpose ______________________________

b. What is the purpose of the air wash system? ______________________

____

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WB 3ABR54530-VIII-9-P5
April 1975

TRACING FLOW OF PRIMARY REFRIGERANT

OBJECTIVE

When you have completed this workbook on the primary refrigerant system of the centrifugal air-conditioning machine, you will be able to correctly trace the flow (cycle) through the system.

PROCEDURES

1. Refer to figure 20, page 39, of study guide 3ABR54530-VIII-9, and color with a light green pencil the condenser water circuit and indicate, with arrows, the condenser water inlet and condenser water outlet.
2. With a lead pencil, darken the chilled water circuit, and indicate, with arrows, the chilled water inlet and chilled water outlet.
3. With a red pencil, color in the high-pressure refrigerant gas and liquid.
4. With a blue pencil, color in the low-pressure refrigerant gas and liquid.
5. Using arrows, indicate the direction of refrigerant flow.

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WB 3ABR54530-VIII-9-P6
April 1975

OPERATING PRINCIPLES OF PURGE RECOVERY UNIT

OBJECTIVE

When you have completed this workbook with no more than four (4) errors, you will be able to identify major components, their functions and how they affect the operation of the Purge Recovery Unit used on the centrifugal air-conditioning machine.

PROCEDURES

Refer to the illustration provided and enter the components and their purposes by the corresponding numbers and then answer the questions following the illustration.

NO.	NAME	PURPOSE
1.		
2.		
3.		
4.		
5.		
6.		
7.		
8.		
9.		
10.		
11.		
12.		
13.		
14.		
15.		
16.		

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NO.	NAME	PURPOSE
17.		
18.		
19.		
20.		
21.		
22.		
23.		
24.		
25.		
26.		
27.		
28.		

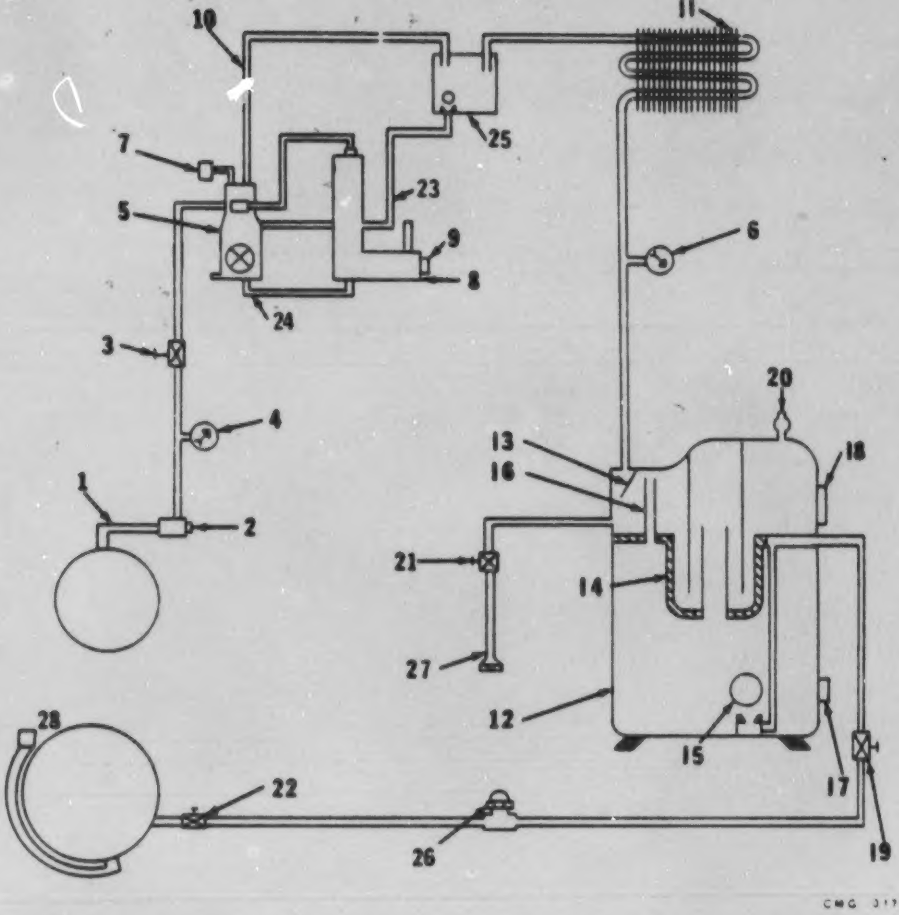
10
11
25
7
23
5
9
8
24
6
3
4
20
13
16
18
1
2
21
14
27
12
15
17
28
22
19
26
CMG 317

Figure 3. Purge Recovery Unit

625

1. What are the noncondensables that the purge unit must remove from the condenser?

____

2. How is the refrigerant returned to the cooler? ____________________

____

3. What causes the refrigerant to condense once it is in the purge unit?

____

____

4. How does the separation chamber separate the refrigerant, air, and water?

____

____

____

____

Checked by ____________________
(Instructor)

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WB 3ABR54530-VIII-9-P7
April 1975

SERVICING CENTRIFUGAL COMPRESSOR LUBRICATION SYSTEM

OBJECTIVE

Upon completion of this workbook on the centrifugal air-conditioning machine compressor lubricating system, you will be able to:

- Identify major components and their purpose.
- Trace the oil flow through the unit.
- Identify required servicing procedures.

You are allowed no more than two (2) errors for each part of this workbook.

Part 1

PROCEDURES FOR MAJOR COMPONENTS AND PURPOSES OF EACH

Refer to figure 4, locate the units shown and enter the components and their purposes by the corresponding number in the following chart.

NO.	NAME	PURPOSE
1.		
2.		
3.		
4.		
5.		
6.		
7.		
8.		
9.		
10.		
11.		
12.		

NO.	NAME	PURPOSE
13.		
14.		
15.		
16.		
17.		
18.		
19.		
20.		
21.		

Part 2

PROCEDURES FOR FLOW OF OIL THROUGH THE UNIT

Using a pencil, draw arrows on figure 4 to indicate the flow of oil through the lubrication system.

Part 3

PROCEDURES FOR SERVICING OF THE LUBRICATION SYSTEM

Using Study Guide 3ABR54530-VIII-9, research and answer the following questions.

1. Gauge pressure on the machine should read approximately ____________ PSIG.
2. Drain oil from the ____
3. Remove the main oil reservoir cover and ______________________________

   ____
4. Remove access bearing cover plate.
5. Explain the procedures used to remove the shaft bearing caps.
6. Fill the bearing approximately __________ of the full charge allowing the excess

   ____

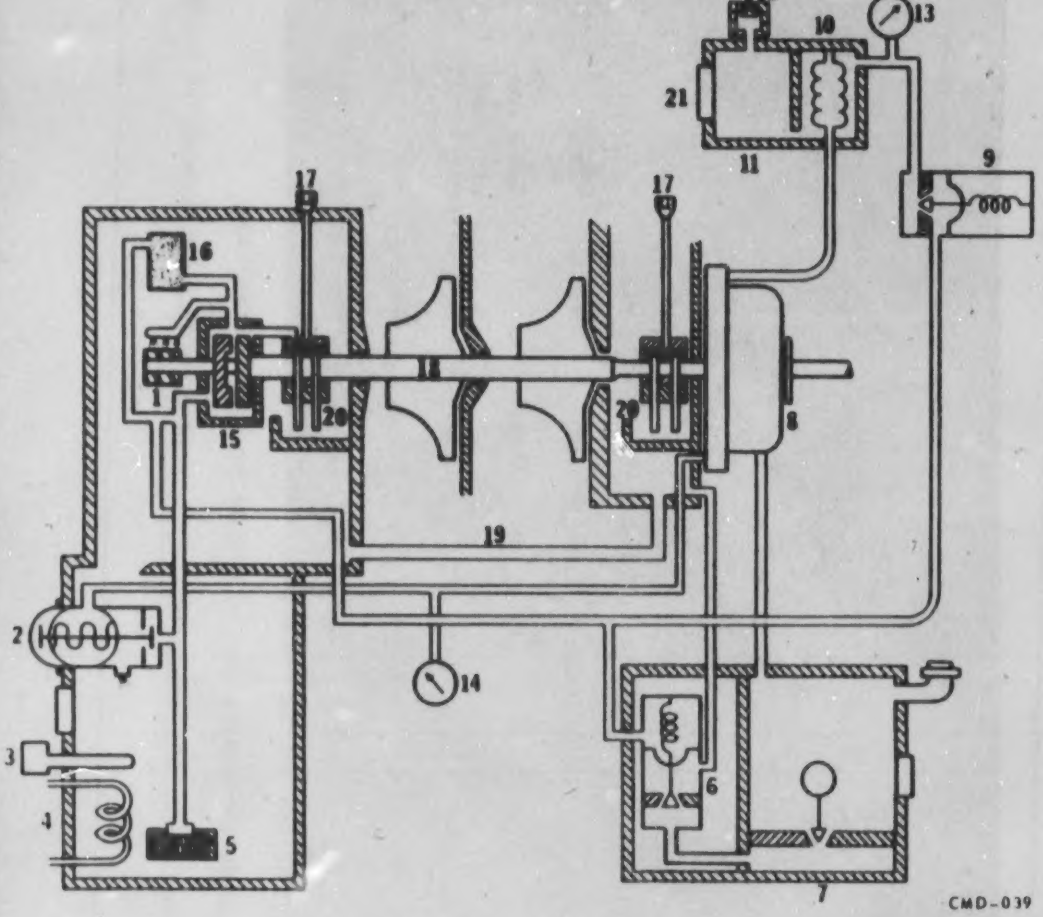
12
13
10
21
11
9
17
17
16
1
15
18
20
20
8
19
2
14
3
4
5
6
7
CMD-039

Figure 4. Lubrication System

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7. Replace the bearing cap and secure.

8. Why must the strainer be removed and cleaned?

9. Drain oil through the plug in the ____

10. Remove the cover from the seal oil reservoir.

11. Remove the filter from the ____

____

12. Refill the reservoir with new oil.

13. Replace the cover and secure nuts ______________________________________

14. Drain the oil in the atmospheric oil reservoir.

15. Remove the oil fill plug and pour oil into the atmospheric oil reservoir until the level is ______________ in the atmospheric float chamber sight glass.

16. Replace the plug and tighten ____

17. What is the last step prior to startup?

18. If level is low after operating for a short time, where do you add oil?

____

CENTRIFUGAL UNIT SAFETY CONTROLS

OBJECTIVE

When you have completed this workbook you will be able to identify the safety controls, their functions and how they affect the operation of the system. You are not allowed any errors.

Part 1

PROCEDURES

Using Study Guide 3ABR54530-VIII-9 and diagram of Safety Control Circuits in the workbook, locate the safety controls shown and enter their name by the corresponding number and state if they are normally open or closed.

Part 2

PROCEDURES

1. Refer to figure 5 of this workbook and list the switches that must be closed:

   a. To start the 100-ton centrifugal unit ______________________________

   ____

   b. For continuous operation of the 100-ton centrifugal unit ______________________________

   ____

   ____

   c. Could the chill water pump interlock prevent continuous operation? Explain your answer. ______________________________

   ____

2. Can the circuit breaker handle be closed if the start button is not closed?

   ____________ Why? ______________________________

3. The low refrigerant temperature control is set to cut-out at ____________ F.

   and set to cut-in at ____________ F.

4. The low chilled water temperature control is set to cut-out at ____________ F

   and cut-in at ____________ F. 611

5. Explain how the start button works in relation to the oil safety switch.

____

____

Part 3

PROCEDURES

Trace the Safety Control

1. Using a red pencil, indicate in figure 5, the starting circuit.
2. Using a blue pencil, indicate in figure 5, the run circuit.

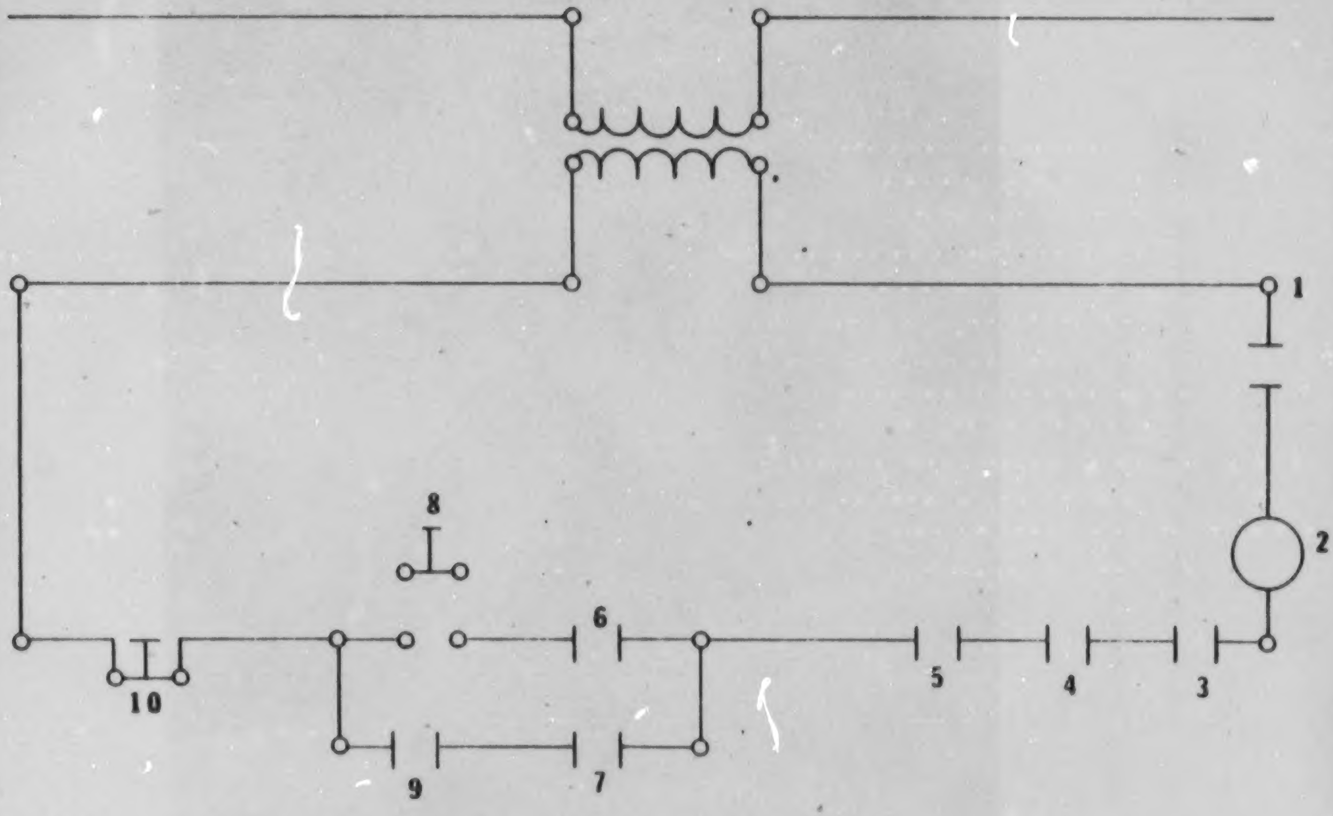
8
6
1
2
10
5
4
3
9
7

Figure 5. Safety Control Circuit

CHARGING PROCEDURES FOR CENTRIFUGAL MACHINE

OBJECTIVE

Using Study Guide 3ABR54530-VIII-9 to answer the following questions with no errors, you will be able to establish the correct procedures for servicing the centrifugal machine with refrigerant.

PROCEDURES

Using Study Guide 3ABR54530-VIII-9, answer the following questions:

1. At what temperature will the drum of refrigerant 11 be under pressure?
2. Where is the charging valve located on the cooler?
3. What pressure should the machine be at?
4. Install a ________ nipple into a ________________ and ________________________ it.
5. Remove the ________________ plug inserted in the ______________ on the drum.
6. What would happen if the nipple were not long enough?
7. What position must the drum be in and why?
8. What is used to connect the drum and the cooler?
9. After the pressure goes above 0 psig, what must be done to lower the pressure?
10. The complete charge of refrigerant is ____________________________.

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PREOPERATIONAL CHECK AND OPERATION OF CENTRIFUGAL MACHINE

Part 1

OBJECTIVE

Using the centrifugal trainer, perform a preoperational check and operate the centrifugal trainer to the specifications outlined in Workbook project VIII-9-10, maintaining optimum efficiency and performance.

PROCEDURES

The instructor will determine whether this exercise is to be performed individually or by groups. After you have the machine running, answer the questions and make adjustments as required for optimum efficiency and performance. Perform the shutdown as outlined in the workbook project when your instructor so indicates.

1. Make sure power is OFF.
2. Check oil levels:
   a. Compressor
   b. Motor
   c. Purge Unit
   d. Suction Damper
   e. Hot Gas Bypass
   f. Speed Increaser
3. Check purge unit water level, refrigerant level and hand valve positions.
   a. Water drain valve - CLOSED. (OPEN ONLY WHEN DRAINING)
   b. Refrigerant gas supply valve - OPEN
   c. Liquid refrigerant return valve - OPEN
4. Start purge unit.

   NOTE: This unit should be started before the centrifugal machine is started and must run continuously while the centrifugal machine is running.
5. Turn power ON.

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6. Start the condenser water pump (located on the Instructor's Panel).

7. Start the chilled water pump (located on the Instructor's Panel).

8. Turn on all auxiliary units - fans, boiler, and hot water pump. (Located on the Instructor's Panel and graphic control panel.)

Starting Water Chiller

1. Set controls: chilled water temperature 45°F; condenser water temperature 85°F.

2. Position the drum controller lever to OFF position - the full resistance position.

3. Make sure the hot gas bypass is CLOSED.

   NOTE: Give the compressor a momentary start to check rotation.

4. Depress start button on circuit breaker panel and hold; close main circuit breaker lever. (Do not force the handle, but make sure it is closed firmly.) Observe the back-of-seal oil pressure gauge. When back-of-seal oil pressure is obtained (needle flickers), about six psi, release the start button and the unit should stay on the line.

   NOTE: Do not hold the start button in longer than 20 seconds. Oil pressure should be developed in 20 seconds; if not, release start button as the oil pump could be inoperative or an oil line may be clogged and the compressor bearing will burn out.

5. Open the cooling water hand valve supplying the compressor oil cooler, speed increaser and seal jacket.

   NOTE: Opening this valve turns the oil heater in the main oil reservoir OFF.

6. Record the following: (After about five minutes operation at speed 1)

   a. Back-of-seal oil pressure ______________________________

   b. Seal chamber oil pressure ______________________________

   c. Suction pressure ______________________________

   d. Discharge pressure ______________________________

   e. Speed increaser oil pressure ______________________________

   f. Bearing temperatures: Seal end __________F; Thrust end ______________F.

Operating Procedures

1. Increase speed to point 5.

   NOTE: When increasing speed, move drum control level rapidly from one point to the next. Never operate the motor between "B" markings. This causes an unbalanced condition in the rotor winding. Let unit operate 15 minutes, after changing speed, before taking readings.

2. Let unit operate at speeds 2 and 3 and make the following recordings:

   a. Condenser inlet temperature ______________________________

   b. Condenser outlet temperature ______________________________

   c. Chilled water inlet temperature ______________________________

   d. Chilled water outlet temperature ______________________________

   e. Suction pressure ______________________________

   f. Discharge pressure ______________________________

   g. Refrigerant condensing temperature ______________________________

   h. Liquid refrigerant temperature ______________________________

   i. Purge unit suction pressure ______________________________

   j. Purge unit discharge pressure ______________________________

   k. Amperage draw ______________________________

Part 2

NOTE: Your insturctor will give you any special insturctions that you may require to prevent damage to yourself and equipment.

1. Centrifugal machine operational controls.

   a. List the controls that operate the centrifugal machine.

____

____

____

____

b. List the controls that will also regulate the cooling capacity.

c. State the set points and explain what the automatic operational controllers do.

d. How does the drum controller reduce the cooling capacity?

2. Chilled water system controls.

a. Can the chilled water be bypassed around the individual cooling coils?

b. How is the chilled water flow controlled at the cooling coil?

c. The chilled water flow is modulated to control what variable.

d. Why does the bypass valve open wider when the cooling coil valves throttle down?

e. Why is the bypass system needed?

f. How is the GPM thru the chiller detected and controlled?

3. Operational adjustments.

   a. Set condenser water controller at 85°F.

   b. Set chilled water controller at 45°F.

   c. Adjust compressor speed to match the load requirements.

   NOTE: Allow time for the system to stabilize after each speed change.

   d. Observe operating conditions.

      (1) Condenser inlet temp. ____________ °F.

      (2) Condenser outlet temp. ____________ °F.

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(3) Chilled water inlet temp. __________ °F.

(4) Chilled water outlet temp. __________ °F.

(5) Suction pressure________________psi or Hg.

(6) Discharge pressure______________psi.

(7) Refrigerant condensing temp. __________ °F.

(8) Liquid refrigerant temp. __________ °F.

(9) Purge unit suction________________psi or Hg.

(10) Purge unit discharge______________psi.

(11) Amperage______________________Amps.

NOTE: Amperage should not exceed 120 amps.

e. Monitor the chilled water temperature.

(1) Check set point and control point (these temps should be almost the same).

NOTE: The temperature difference between entering and leaving chilled water that is used by most manufacturers is 10°F. The 10°F TD provides the most economical operation with water chilling machines.

(2) If the TD and leaving chilled water temperature are not correct, adjustments to the controls may be required.

NOTE: If you think the chilled waterflow is not right, check with the instructor before making any adjustments.

Stopping Procedures

1. Depress stop button or trip main circuit breaker switch.
2. Move drum control lever to OFF.
3. Close water coolant valve.

   NOTE: Closing this valve turns on the heater in the main oil reservoir, which keeps refrigerant gas from condensing into the oil (red indicator light).
4. Stop purge unit.
5. Turn off condenser water pump.

6. Turn off chilled water pump.
7. Turn off hot water pump.
8. Turn off all auxiliaries on Instructor's and graphic control panel.

DIAGNOSE TROUBLES IN THE CENTRIFUGAL SYSTEM

OBJECTIVE

Without referring to Study Guide 3ABR54530-VIII-9, you will be able to list the probable causes and remedies for the following troubles on the centrifugal air-conditioning machine from memory.

PROCEDURES

Answer the questions below.

1. High head pressure

   a. Probable cause

   ____

   ____

   ____

   ____

   b. Remedy

   ____

   ____

   ____

   ____

2. Loss of capacity

   a. Probable cause

   ____

   ____

   ____

   ____

b. Remedy

3. Compressor surges

a. Probable cause

b. Remedy

4. Compressor second stage frost

a. Probable cause

b. Remedy

5. Speed increaser overheated

a. Probable cause

b. Remedy

Your instructor will place troubles in the centrifugal machine. Observe the unit's operation and complete the following chart.

	TROUBLE	PROBABLE CAUSE	REMEDY
a.			
b.			
c.			

Checked by ______________________
(Instructor)

ATC-SHEPPARD AFB TEX. 78-1970

STUDY GUIDES
3ABR54530-IX-1 and 4

Technical Training

Refrigeration and Air-Conditioning Specialist

EVAPORATIVE COOLING SYSTEMS AND CIVIL ENGINEERING MAINTENANCE MANAGEMENT

December 1975

USAF SCHOOL OF APPLIED AEROSPACE SCIENCES
Department of Civil Engineering Training
Sheppard Air Force Base, Texas

11-8

Designed For ATC Course Use

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This supersedes SGs 3ABR54530-IX-1 thru 4, WBs 3ABR54530-IX-1-P1 thru IX-4-P2, November 1973. (Copies of the superseded publication may be used until the supply is exhausted.)

Department of Civil Engineering Training
Sheppard Air Force Base, Texas

SG 3ABR54530-IX-1
December 1975

EVAPORATIVE COOLING SYSTEMS

OBJECTIVES

To help you in learning to:

- Operate and maintain cooling equipment.
- Locate, identify, and give the function of the major components.
- Trace the flow of air and water through the system.

INTRODUCTION

SECTION I

EVAPORATIVE COOLING

Can you recall your days at the local bathing pool, or perhaps at the beach? If a slight wind was blowing, you will remember that you were more comfortable in the water than out of it. When you climbed out of the pool, the water in your wet bathing suit evaporated rapidly to leave your skin chilled from the loss of heat. Though you didn't give it much thought at the time, you were really experiencing evaporative cooling.

Applying the same principle, our older surgeons used an ether spray to freeze those portions of the skin in which incisions were to be made. Rapid evaporation of the ether reduced the temperature of the skin and underlying flesh to the freezing point. You can demonstrate this principle for yourself by wetting your hand with alcohol or water and holding it in the airstream from a fan.

Principle of Evaporative Cooling

In an evaporative cooler the air is drawn through a finely divided water spray or a wet pad so that a portion of the water is being continually evaporated. The latent heat of evaporation, which must be passed on to the water to evaporate it, is suppled from the heat of the incoming air, thus reducing the dry-bulb temperature of that air. In evaporative cooling there is always a drop of the dry-bulb temperature, an increase in the relative humidity and dewpoint temperature, and an unchanged wet-bulb temperature.

The water, which is recirculated continually through an evaporative cooler, assumes the wet-bulb temperature of the entering air after a short period of operation. The recirculated water will remain at the air wet-bulb temperature with no external heating or cooling. Makeup water is added to replace the evaporated water.

The temperature reduction, which can be made in the air passed through an evaporative cooler, depends entirely on the wet-bulb temperature of the air which is to be cooled. The wet-bulb temperature of the air entering the evaporative cooler is at the lowest temperature to which the circulating air may be cooled. Since an external source of heat is not used to evaporate the water, the process of evaporative cooling is called an adiabatic process. (A process in which heat does not flow into or from the system of the process, although thermal changes may occur within the system.)

Evaporative cooling should not be used to cool air for spaces requiring constant temperature and humidity control, such as hospital operating rooms and certain types of highly technical electronic equipment. Evaporative cooling is best suited and chiefly used for cooling the space for the comfort of personnel.

Application of Evaporative Cooling

As we have shown, evaporative cooling depends on the evaporation of water; thus, it can be successful only under atmospheric conditions of a low relative humidity. It can be used only where the difference between the outdoor wet-bulb and dry-bulb temperature is relatively high. In the arid regions of the southwestern United States, where there is low relative humidity, properly installed and operated evaporative cooling units cool comfortably. This type of system brings in 100 percent outside air. It may be equipped with a humidistat so that when the inside humidity is high and the cooler cannot function properly as an evaporative cooler, the water is cut off and the unit can operate as a straight mechanical ventilating unit. Whenever the outdoor wet-bulb temperature is 73° F or lower, effective cooling and indoor comfort can be maintained by evaporative cooling.

The leaving air temperature of an evaporative cooler usually is just short of saturation, that is, the dry-bulb temperature of the air leaving a cooler does not quite reach the wet-bulb temperature of the air entering the cooler. An evaporative cooler operating at 90 percent efficiency will cool the air a number of degrees equal to 90 percent of its original wet-bulb depression. The measure of the approach to the entering wet-bulb temperature is the saturation efficiency of the cooler. Air entering at 95° dry-bulb and 75° wet-bulb will be cooled to 77° if the cooler is operating at 90 percent efficiency. Computation: The depression amounts to 95° (dry-bulb temperature) minus 75° (wet-bulb temperature) or 20°. Ninety percent of 20 is 18. Subtract 18° from 95° (the dry-bulb temperature) and you have 77°, which is the temperature to which the air is cooled.

Types of Evaporative Cooling Units

There are two main types of evaporative coolers: drip and spray. However, these are further broken down into rotary-drum, slinger, and air washer units. No matter what type is used, the principles of evaporative cooling which was explained in section II are the basis of its success.

Cabinets for evaporative coolers, which enclose the entire assembly of the cooler, are usually constructed of heavy-gage sheet metal or aluminum. The louvered sides of the cabinets are removable to provide access to the pads and equipment inside the cabinet.

Components of Evaporative Cooling Units

Components of evaporative cooling units are very much the same in each type except that some have a different method of supplying the water to the evaporating pads.

DRIP UNITS. Typical drip-type evaporative cooler components consist of the following: a motor-driven fan, or blower; a circulating water pump, piping, and water distributors; a water collecting pan with water makeup float valve, and drain; and water evaporating surfaces. All these components are assembled in a weatherproof cabinet, the complete assembly being known as a self-contained unit. It will range in size from the small, one-room cooler with a capacity of about 700 cubic feet per minute (cfm) to the large industrial coolers with capacities up to about 30,000 cfm.

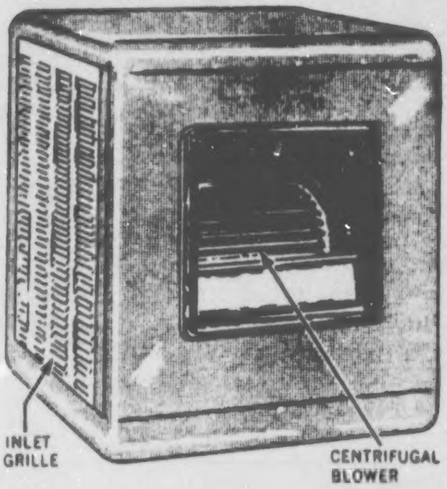


Figure 1. Drip-Type Evaporative Cooler With Centrifugal Blower

The small, one-room cooler normally uses a propeller fan; the larger coolers use a squirrel-cage or centrifugal blower. The propeller fan cooler discharges the cooled air directly into the space to be cooled, from the vaned air-discharge outlet of the unit. Duct work for air distribution is never attached to this type unit.

Coolers of about 2000 cfm capacity and above, as we have pointed out, use the squirrel-cage blowers which are driven by a motor with a V-pulley and a V-belt. Figure 1 illustrates this type, and figure 2 shows the unit disassembled. Electric motors vary in size according to the size of the fan blade or blower.

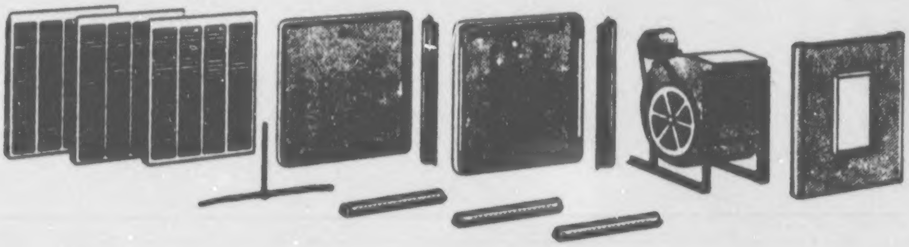


Figure 2. Drip-Type Evaporative Cooler Disassembled

The recirculating water pump is usually a vertical-shaft, directly connected unit of light construction and low head pressure. The pump impeller is suspended in the pump housing from a ball-bearing motor shaft, which eliminates pump bearings and packing. The pump housing usually has a wire-mesh screen through which the water passes as it is drawn in by the pump impeller and forced through the discharge tube to the distributor. Pumps usually sit in the water of the collecting pan or are sometimes mounted on a special frame. In either case, they must be insulated to prevent vibration and transmission of noise. Figure 3 illustrates this type of water pump and its breakdown.

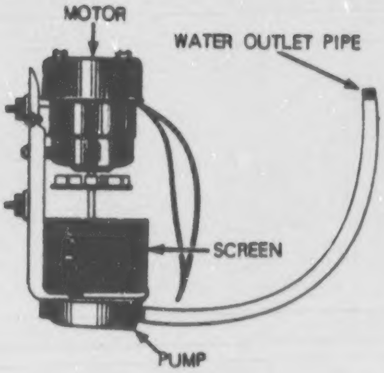

MOTOR
WATER OUTLET PIPE
SCREEN
PUMP

Figure 3a. Recirculating Water Pump

A water distributor is a trough which receives the water from the recirculating water pump through the distributor head and distributes it evenly over the top of the evaporating surface pads. One distributor is provided for each pad in the cooler. The water flows through weirs (triangular openings) of the trough onto the pads which are on the air inlet sides of the cooler. See figure 4.

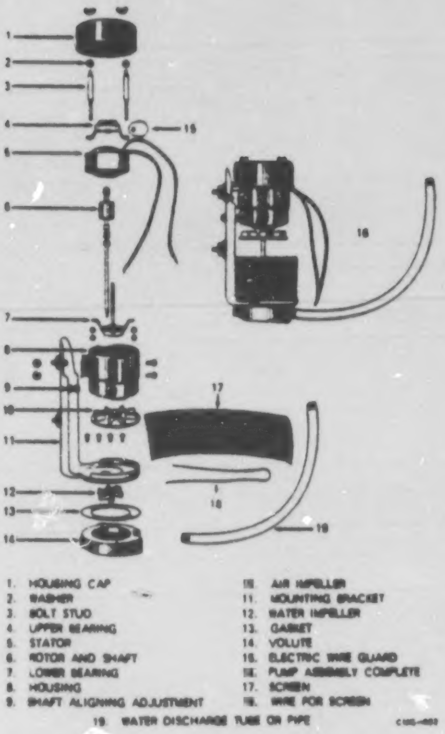

1. HOUSING CAP
2. WASHER
3. BOLT STUD
4. UPPER BEARING
5. STATOR
6. ROTOR AND SHAFT
7. LOWER BEARING
8. HOUSING
9. SHAFT ALIGNING ADJUSTMENT
10. AIR IMPELLER
11. MOUNTING BRACKET
12. WATER IMPELLER
13. GASKET
14. VOLUTE
15. ELECTRIC WIRE GUARD
16. PUMP ASSEMBLY COMPLETE
17. SCREEN
18. WIRE FOR SCREEN
19. WATER DISCHARGE TUBE OR PIPE

Figure 3b. A Recirculating Water Pump Breakdown

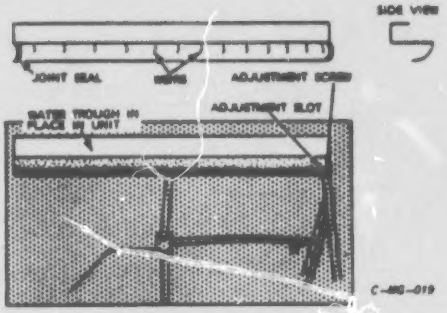

SIDE VIEW
JOINT SEAL
WEIRS
ADJUSTMENT SCREW
ADJUSTMENT SLOT
WATER TROUGH IN PLACE IN UNIT
C-MG-019

Figure 4. Water Trough Distributor

The piping system consists of a T-fitting or a water distributor head with one inlet and three outlets which are connected by pipe or tubing to the water distributors. The inlet connection from the pump is usually a rubber hose. In figure 5 you can see that the quantity of water which flows to the branch piping system is regulated by an adjustable hose clamp which throttles the flow of water in the hose connecting the water pump to the water branch tubes. The quantity of water which flows through the branch tubes to the troughs is equalized by rubber or metal metering rings placed in each branch tube.

The water collecting pan forms the bottom of the cooler and contains the water, the water float makeup valve, and an overflow pipe (see figure 6). The makeup valve controls the level of the water in the collecting pan and automatically admits water to replace any lost through the system, evaporation, and bleedoff. Water in the collecting pan should be kept at a depth sufficient to keep the recirculating pump primed. The overflow pipe consists of a removable length of pipe, the top of which is slightly below the top edge of the collecting pan. When the water level in the collecting pan rises to the top of the overflow pipe, the excess water flows into the pipe and is carried away to a drain.

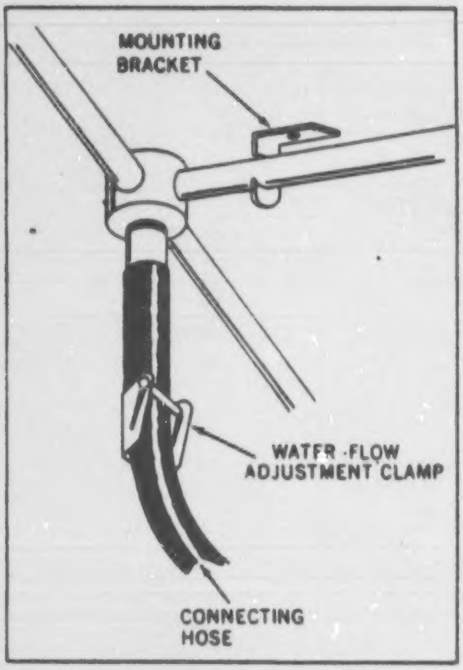


Figure 5. Water Distributor Header

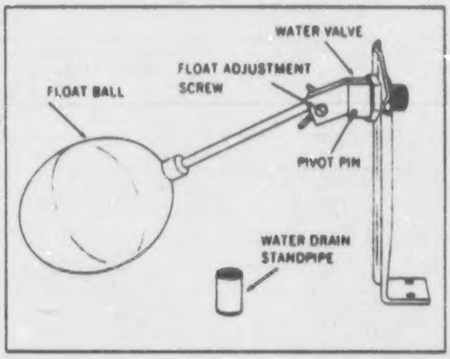
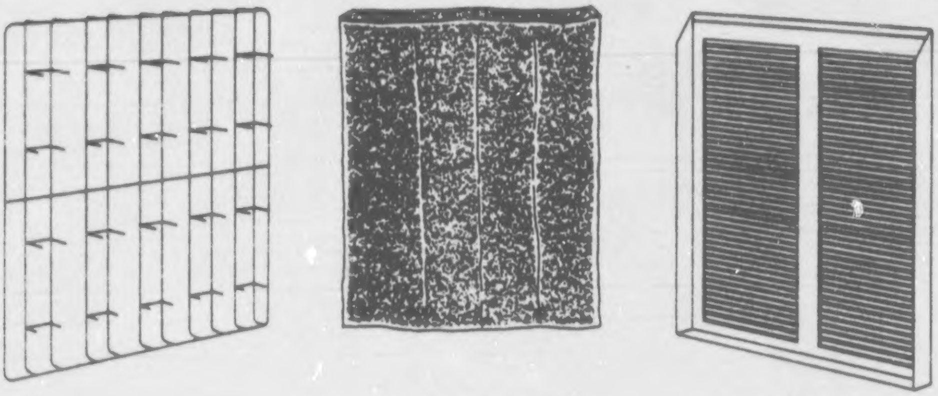


Figure 6. Float Valve Assembly

The water evaporative surface of drip-type evaporative coolers consists of one or more pads of aspen wood excelsior, redwood excelsior, a mixture of redwood and aspen wood excelsior, glass wool, or a fiber made of other materials. The bulk excelsior is inserted in either cheesecloth, hardware cloth, or a metal frame to bind and hold the material together in pads. The pads are held in place by a barbed rack or other suitable means. Each pad is placed in a louvered frame, as you can see in figure 7. The louvered frames are fitted into openings on two sides and on the back of the cooler through which the air is drawn by the fan. The louvers serve a double purpose: they help to distribute the air uniformly over the entire area of the water evaporating pads, and they prevent water from wetting the area surrounding the cooler.

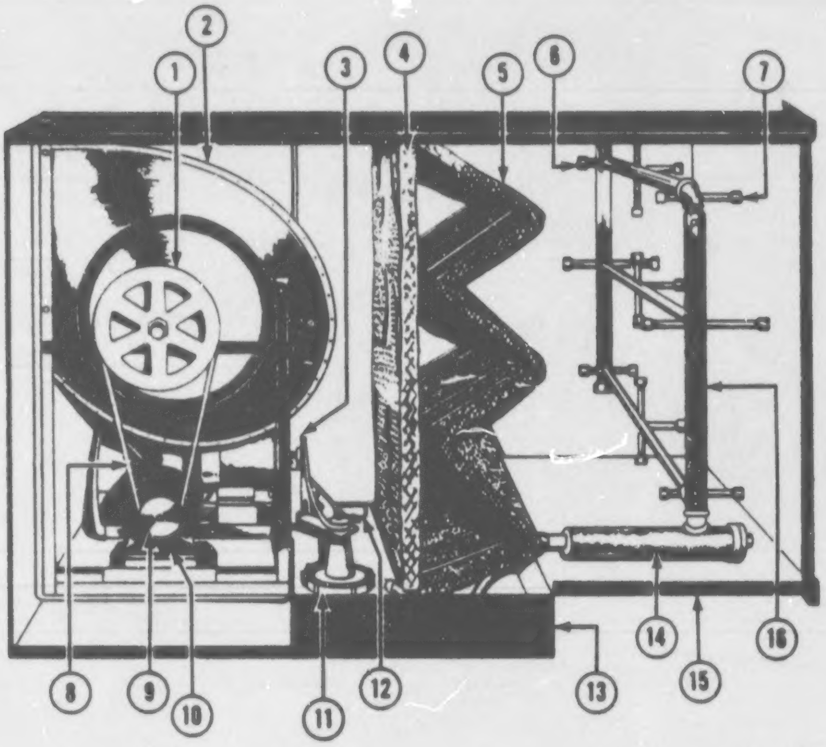


BARBED RACK FIBER PAD AIR INLET GRILLE

Figure 7. Grill, Rack, and Pad, Disassembled

SPRAY UNITS. Spray units (sometimes called air washer units) are made in sizes ranging from 3500 cfm through 12,000 cfm. They are larger in dimension and weigh considerably more than the drip-type unit. They are designed to keep the pads free of excess dust and water solids for a longer period of operating time than the drip-type units. They use sprays to wet and continuously wash down the inlet side of the filter pads and partially saturate the incoming air by direct contact as the air passes through the sprays.

There are two main types of spray designs used by manufacturers, with essentially the same results. These are the "spray nozzle" and the "rotating disk" (sometimes called slinger), shown in figures 8 and 9. Both spray-type units consist of the following principal components: piping; water collecting pan with makeup float valve and drain; recirculating water pump; evaporative filter and eliminator pads; the sprays, either nozzles or spray disk; and a motor-driven blower--all assembled in a self-contained weatherproof cabinet.



1. BLOWER DRIVE
2. BLOWER HOUSING
3. PUMP MOTOR AND DRIVE
4. ELIMINATOR PAD
5. FILTER PAD
6. PAD WASH DOWN SPRAY JETS
7. AIRSTREAM SPRAY JETS
8. BLOWER DRIVE BELT
9. BELT DRIVE PULLEY
10. MOTOR
11. WATER PUMP
12. WATER FLOAT CONTROL
13. WATER SUMP AND MAKEUP PAN
14. WATER SURGE CYLINDER
15. SPRAY DRAIN PANEL
16. WATER SUPPLY HEADER

Figure 8. Sectional View of a Spray Nozzle Unit

Piping consists of the supply line and piping to the spray nozzle. The collecting pan forms a part of the bottom of the evaporative cooler cabinet, which contains the float-actuated water makeup valve and the drain. Since the float controls the water valve, it also controls the level of the water in the collecting pan. The spray disk or wheel assembly of the evaporative cooler supplies a continuous sheet of atomized water over the air inlet face of the evaporative filter pad. The spray disk collecting pan is located below and in front of the center of the filter pad. The water in the collecting pan is supplied to the disk or wheel by a water pump similar to those used on drip-type units. The centrifugal action of the rotating disk distributes the water evenly in all directions in a vertical plane so that the resulting curtain of spray water falling over the entire inlet face of the evaporative filter pads washes down the air inlet side of the pads continuously.

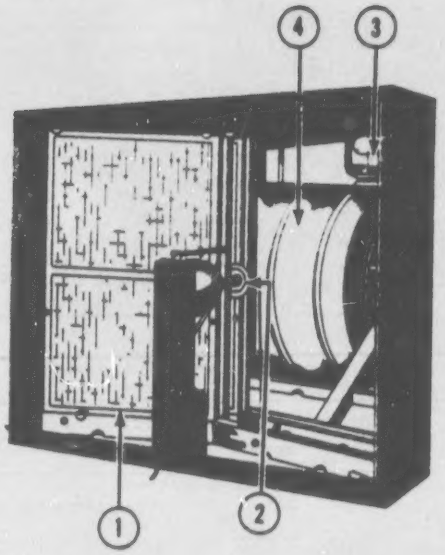


Figure 9. Rotating Disk Unit

The automatic flush valve consists of an electrically operated solenoid valve and an electric timer combined in one unit. This valve flushes the water from the water collecting pan regularly and automatically. This action helps to keep the collecting pan clean. The solenoid valve is operated by means of a coil of wire wound on a soft iron spool which forms an electric magnet. When the current flows through the coil, the valve stem is lifted to open the valve. When current is cut off, the valve is closed either by gravity or by a spring. The operating solenoid part of the valve is completely enclosed. The water drain is controlled by a plunger, and a diaphragm isolates the working mechanism of the valve from the water. The valve assembly is also provided with an overflow connection and a manual operating lever to completely drain the water collecting pan.

The electric timer regulates the flushing action of the solenoid valve. It consists of a 1-hour electric timeclock which is adjustable from 0 to 2 1/2 minutes' drain time. The setting of the drain time will depend on the dirt content of the air entering the cooler, the salt content of the water, and the resistance in the waste plumbing.

The spray nozzle does the same things as a spray disk. Nozzles are usually mounted in both a vertical and a horizontal position; the vertical nozzles are used for washing down the evaporative filter pads, and the horizontal nozzles for forming a curtain of spray water over the entire air inlet area. Water is supplied to the nozzles through the piping system by a centrifugal pump of large capacity and heavy-duty construction, mounted in the water collecting pan. This type of water pump is completely sealed. All recirculating water pumps have a screen of some type to prevent particles of dirt and foreign matter from getting into the water piping system.

Evaporative filter pads and eliminator pads are usually made of fibers of various materials and are supported by angle frames and heavy wire mesh. Normally, spray-type evaporative coolers use a specially treated hygroscopic spun glass for filter pads. This material assists in holding the fibers in place and helps the water adhere to the surface. The evaporative filter pads form the water evaporating surface. The eliminator pads remove the moisture from the cooled air after it leaves the evaporative filter pads and prevent water drops from being carried over into the fan and motor of the cooler unit.

Blower fans, known also as centrifugal fans, are used on spray-type units. The fan and the motor which drives it are both equipped with grooved-type pulleys and are connected with V-belts. The fan has a self-aligning, self-oiling bearing on each side of the impeller wheel. Blower fans are designed and rated for air delivery against 1/4-inch water gage static pressure resistance at the discharge outlet of the unit. Blower fans, depending on size, are normally used to supply air through a duct system.

ROTARY-DRUM EVAPORATIVE UNITS. As the name implies the rotary-drum evaporative cooling unit uses a rotating drum, powered by a reduction gear and motor. Figure 10 illustrates a partly dissembled rotary-drum unit. Other principal components are the exterior air-filter unit, the rotor housing, the water tank and the float-actuated water makeup valve, an automatic flush valve, and a motor-driven fan or blower. All of these components are mounted in a metal weatherproof cabinet. The rotary-drum-type evaporative coolers are usually made in sizes ranging from 2500 through 6000 cfm. Blowers and motors are designed the same as for the drip-type evaporative cooler units.

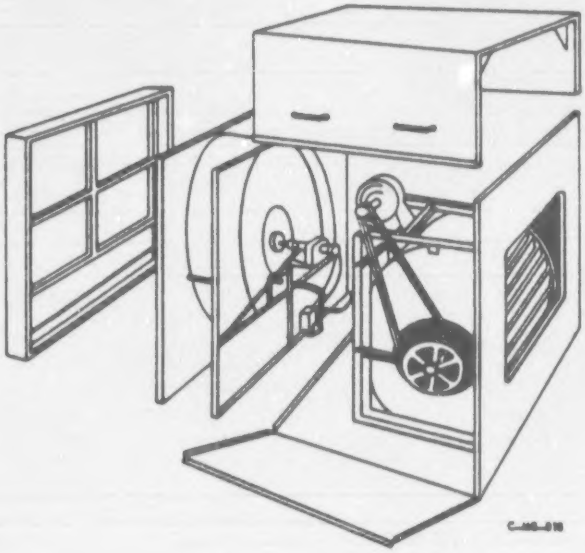


Figure 10. Rotary-Drum Unit (Partly Disassembled)

The rotor, which is driven by an electric motor at an approximate speed of 1 1/2 rpm, is cylindrical and consists of alternate layers of corrugated and flat screen wound on a drum. It revolves in the rotor housing, the lower portion being constantly wet by its immersion in the water tank of the housing. When in operation, the rotor continuously exposes an evenly wetted surface to the incoming air. The rotor housing contains the revolving rotor and supports the rotor bearings and the electric gear motor. The lower portion of the rotor housing forms the water tank. The float-actuated water makeup valve controls the water level in the tank.

The automatic flush valve empties the water from the tank automatically. This action, which helps to keep the rotor and water tank clean, is repeated regularly by an electrically operated solenoid valve. The operating solenoid of the valve is completely enclosed. The water drain is controlled by a plunger, and a diaphragm isolates the working mechanism of the valve from the water. The valve assembly is provided with an overflow connection. A manually operated valve is also provided to drain the water tank completely.

The action of the solenoid valve is regulated by an electric timer, a 1-hour electric timeclock with contacts that open and close according to the time limit for which the timer is designed. The setting of the drain time, usually adjustable from 0 to 2 1/2 minutes, is dependent on the amount of dirt in the air that enters the cooler, the salt content of the water, and the resistance in the waste or drain plumbing.

The filters of the rotary-drum-type evaporative cooler, called air filters, are usually of the impregnated, washable, metal type. The filter unit is located on the air intake side where the air can be cleaned as it enters the cooler.

SLINGER-TYPE EVAPORATIVE UNITS. The slinger-type unit may be constructed as a double unit. The metal weatherproof cabinet may contain two sets of the principal components, such as one or two sets of spray wheel assemblies, one or two sets of evaporative and eliminator pads, one or two automatic flush valves, one electric timer, and one motor-driven blower. The blower, or fan, of the slinger-type evaporative cooler is the same as on the rotary-drum unit--a motor-driven centrifugal blower. It is driven by a V-belt connecting the blower and motor by means of grooved pulleys. The blower, which is used to supply air through the duct system, is designed and rated for air delivery against 1/4-inch water gage static pressure resistance at the discharge outlet. It has two self-aligning, self-oiling bearings, one on each side of the blower wheel. The electric motor operating the blower is mounted high in the metal cabinet to protect it from too much moisture.

The electric motor operating the spray wheel is sealed in a waterproof assembly with water-seal packing around the shaft to the spray wheel. The spray wheel picks up water from the collecting pan and distributes it in all directions in a vertical plane by the centrifugal action of the rotating spray wheel. This action supplies a continuous sheet of atomized water which is sprayed over the air inlet side of the evaporative filter pad. As the air passes through the water, dust and dirt is removed and the air is partially cooled. This continuous sheet of atomized water also continually washes the dirt from the pad. The water collecting pan, which is located below and in front of the evaporative filter pad, forms a part of the bottom of the evaporative cooler cabinet. A float-actuated water makeup valve, which controls the level of water, is contained in the collecting pan.

The automatic flush valve assembly consists of the flush valve, which flushes the water from the water collecting pan regularly and automatically; the solenoid valve; and timer. The timer is electric and has an adjustable drain-time setting which regulates the flow of current to the solenoid valve. The solenoid valve operates the drain valve. This assembly is very similar to the flush valve assembly used with the rotary-drum-type evaporative cooler.

The evaporative and eliminator pads are usually made of various washable materials supported by angle frames and heavy wire mesh. The fibers are impregnated with a material which not only helps to hold the fibers in place but also treats the fibers so that water will adhere to their surface. The evaporative filter pads form the water filter and evaporating surface, and the eliminator pads remove moisture from the cooled air. The eliminator pads also prevent small drops of water trapped in the air from being carried over into the fan and motor of the blower compartment.

The cabinets for slinger-type evaporative coolers are usually constructed the same as those for other large type evaporative coolers. Heavy-gage galvanized steel is used to enclose the entire unit. The sides are removable to provide access to the interior.

When the efficiency of an evaporative cooler falls below 80 percent, corrective action should be taken to improve its operation. Air velocity through the evaporative pads should not exceed 300 feet per minute. Air changes within the space being cooled should be at the rate of 30 times per hour. The air velocity within the duct system should not exceed 1200 feet per minute for quiet operation.

QUESTIONS

1. Name the two main types of evaporative cooling units.

2. For what is evaporative cooling normally used?

3. Explain where evaporative coolers may be operated with relative success.

4. Which type evaporative cooler does not use a duct system for air distribution?

5. Squirrel-cage blowers are generally used on what size evaporative cooler?

6. How are squirrel-cage blowers driven?

7. On operative cooler units that have an automatic flush valve, what regulates the action of the solenoid valve?

8. Corrective action should be taken when an evaporative cooler falls below what degree of efficiency?

9. What should be the maximum air velocity through the evaporative pads?

10. What should be the hourly rate of air change within the space cooled?

SECTION II

INSTALLATION AND OPERATION OF EVAPORATIVE COOLING SYSTEMS

INTRODUCTION

Long before the refrigeration coil became the basis of air-conditioned comfort, evaporative coolers and cooling systems were being used to some extent in semiarid and arid states--Kansas, Colorado, New Mexico, for example--where the daily humidity was usually very low. Even today, Air Force bases located in dry climates employ this type of cooling with considerable success at a low cost.

The small units are usually mounted in the window of a building. The larger units, however, must be placed on substantial structures that will support their weight.

INSTALLATION PROCEDURES

The size and style of the unit determines the location and the type of structure required.

Locations

Units mounted in building windows are of the small blower type. These are light in weight and will not do damage to the building structure. See figure 11A.

The large, heavy units must be mounted on self-supporting platforms adjacent to, but independent of the building (see figure 11B). In some cases--the air-washer-type unit, for instance--it may be more economical to mount the unit on a cement platform.

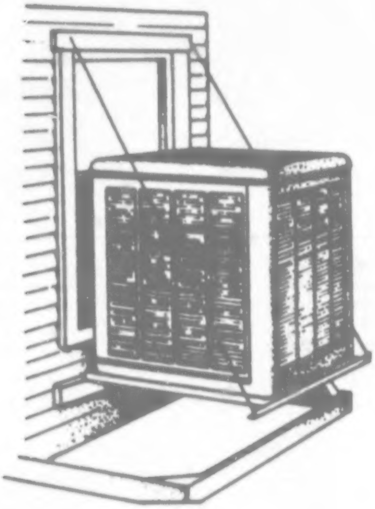


Figure 11A. Window Unit

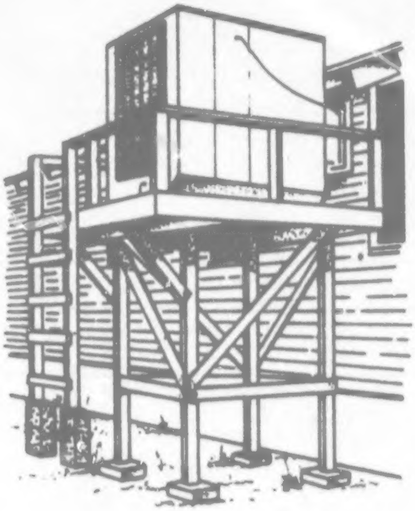


Figure 11B. Large Blower-Type Unit on Mounting Structure with Guardrails and Ladder

Structures

The dimensions and operating weight of the cooler should be determined before starting construction of the supporting structure or mounting platform. A walkway with guardrails around the cooler should be provided for the safety of the serviceman and to give him proper access to the equipment for making repairs. Each platform should also have a ladder built as part of the structure. See figure 11B.

Never mount cooler units on the building roof. Each unit must be mounted on the platform so that it is rigid and level. In some cases this may require shims and the bolting down of the unit. Every cooler manufacturer furnishes mounting and installation instructions with each type unit. Personnel who are assigned to mount cooler units should read carefully and understand these instructions.

Connections

The various connections required for evaporative coolers must be installed as specified for each cooler. Check the instructions and see that the proper-size pipe, valves, switches, wire, and fuse boxes are installed. Only in this way can you be sure that the equipment will give the expected service.

WATER SUPPLY AND DRAIN. The small, window-type evaporative cooler normally uses 1/4-inch copper tubing to carry the water supply. A 1/4-inch fitting is located on the side of the sillcock valve which is installed on any ordinary 3/4-inch outside water valve (garden hose).

Larger units must have a water supply line of at least 3/4-inch pipe or tubing. A globe shutoff valve should be installed in the supply line on the inlet side to the unit. Coolers using a water solenoid valve instead of a recirculating pump should have a water strainer installed on the inlet side of the solenoid valve. A water faucet with a hose bibb should be installed in the supply line near each cooler to be used in washing down the interior of evaporative coolers immediately after heavy dust storms or when maintenance service is being done

The water drain or waste system for evaporative coolers should be at least 1 1/4 inches in diameter to reduce drain stoppage. The drain system should be connected to the sewer or to a street drainage system. In freezing areas the water supply system should be insulated against freezing, or the unit may be installed to permit the complete draining of the system.

ELECTRIC CONNECTIONS. Small units (window-type) are usually connected by inserting the electric cord plug into a convenient outlet. Thus, they can be placed in or out of operation by a toggle switch on the front of the unit.

The larger units should be equipped with their own fuses. Sometimes this may require a separate main switch and fuse box, depending on the power requirements of the unit. Pushbutton stations or toggle switches are used to start and stop equipment operation. Other units may require separate switches for the water recirculating pump motor and the blower motor. The larger units usually require magnetic starters and sometimes have pilot lights or other devices to indicate when and what part of the cooling unit is in operation. All switches, controls, pilot lights, and indicators should be mounted on a control panel which is located in a convenient place.

Each large evaporative cooler should have a disconnect switch mounted inside the unit to permit maintenance personnel to control the unit operation while performing maintenance service. This is a time-saving move as well as a safety measure.

STARTUP CHECKS AND ADJUSTMENTS

The successful functioning of evaporative air coolers depends directly upon the manner in which they are operated. Normally, the using organization is responsible only for starting and stopping evaporative air cooling units and systems. Instructions for the operation of these coolers are prepared by the Air Installations Office and are usually posted on the cooler switch panel for ready reference. The personnel of the using organization are instructed thoroughly in the operation of electrical switches, water valves, and other controls. They are cautioned not to start the blowers prior to starting the water pumps after long shutdown periods. As we have already pointed out, during periods of high outside relative humidities and when the humidity within a room becomes too high for comfort, evaporative coolers should be operated only as ventilating systems. The necessity of keeping a sufficient number of windows raised at all times while the coolers are in operation is also stressed. The systems are operated only when required and are shut off by the using organization when the temperature does not warrant their use.

Startup Procedures

When a new or inactive evaporative air cooling unit is to be placed in service, the refrigeration and air-conditioning shop maintenance personnel perform the startup services to prepare the equipment for operation. Before starting the equipment, they inspect all parts, accessories, and units to see that they are secure and correctly adjusted. Seasonal startup is scheduled well ahead of the time the equipment is to be used. This allows ample time for inspection and startup services. During initial startup procedures, all supply outlets, vanes, dampers, and splitters should be opened for normal airflow. Moist rags should be placed over the supply air outlets into each space being air conditioned to catch the dust and construction dirt before it is discharged into the space where occupants are on duty.

The ratings of motor overload protection devices should be checked against the motor nameplate ampere ratings. If the devices are oversize or undersize, thermal elements of the proper size should be installed.

An ammeter should be connected to the blower motor circuit by an electrician prior to starting the motor. Starting and running currents should be recorded when the blower is first operated, with all pads and filters dry and in place. If the running current is equal to or less than the overload rating of the motor, then the motor will not be overloaded under final load conditions.

Testing the unit with clean, dry pads assures you that the unit can be operated subsequently without water for ventilating purposes since pads are always in place when the unit is operating. If the running current is in excess of the motor overload rating, you must determine the cause. In many cases, overload is due to excessive fan speed. Correct this before continuing the operation of the motor. The fan speed should be reduced by adjusting the variable-pitch motor pulley or reducing the size of the motor pulley. Where this is impractical, the blower pulley size should be increased. You should use pulleys of the correct size rather than attempt to cut down the original ones. An ammeter should be used to check the starting and running currents of the pump motor after the water collecting tank has been filled and the pump first operated. If the running current is in excess of the motor overload rating, determine the cause and correct it before continuing the operation of the pump.

During the initial operation of the unit with water on the pads or sprays, air delivery in the supply ducts should be determined by a velometer or other velocity-indicating instrument. Take readings at a sufficient number of cross-sectional spots in the same section of the supply duct so that you can arrive at an average velocity reading. Multiply the average velocity by the square-foot, cross-sectional area of the duct. This computation will give the quantity of airflow in cubic feet per minute. If the rate of air delivery approximates the designed capacity of the system, the unit should be continued in operation. If the rate of air delivery is considerably in excess of design capacity, reduce the fan speed. In such a case, the fan motor is usually overloaded and the velocity of the air through the water evaporating pads is excessive. If this is the case, drops of water may be carried over into the fan compartment and cause shorting of electrical circuits, motor "burnouts," rapid deterioration of belts, and excessive rust and corrosion. After balancing air distribution to all spaces by the use of velocity indicating instruments, lock all dampers, splitters, and directional flow vanes in their final position in such a manner that tampering or readjustment is impossible except by the maintenance personnel. Units which operate at efficiencies below 80 percent require adjustment to improve their performance.

Thermostat and humidity controls, when used, should be tested for automatic operation, set at the proper settings, and locked to prevent tampering or readjustment by other than maintenance personnel.

Shutdown Services

When evaporative air cooling equipment is to remain idle for long periods of time the refrigeration and air-conditioning personnel perform the preventive maintenance shutdown services. This service protects the equipment, conserves critical materials, and prepares the equipment for minimum startup service. All parts, accessories, and equipment are inspected to insure proper servicing for seasonal shutdown or standby condition.

The shutdown service for evaporative air cooling equipment depends upon its condition and the method of storage. Usually, the coolers are drained and washed out with water under pressure. If they are to remain attached to the building, they should be protected from the weather by some type of cover. Normally, these coolers should be removed from the building, stored in a dry place, and overhauled during the winter season. This procedure puts the coolers in good condition for the next season's run. Having been overhauled, they should give very little trouble during the cooling season.

QUESTIONS

1. Name the type of evaporative cooling unit that is installed in building windows?

2. Why should evaporative coolers have a waste drain of at least 1 1/4 inches in diameter?

3. What type of evaporative cooler is connected by inserting the electric cord plug into a convenient outlet?

4. How do maintenance personnel control the operation of a large evaporative cooling unit when performing maintenance?

5. What is the minimum square feet of louvered exhaust opening per 1000 cubic feet of air delivered to a room or area?

6. Why is a thermostat used on an evaporative cooling unit?

7. What does a humidistat control?

8. Which components of an evaporative cooling system should be locked in position and why?

9. Who usually operates evaporative cooling systems?

10. Why should the water pump motor on drip- and slinger-type evaporative coolers be placed in operation at least 15 minutes before starting the system blower?

SECTION III

INSPECTION AND MAINTENANCE OF EVAPORATIVE COOLERS

INTRODUCTION

At many installations improper maintenance of evaporative cooling units has resulted in excessive costs for renovation. These units are exposed to water and atmospheric elements continuously. Consequently, where maintenance is lax, complete deterioration of surfaces such as panels, blowers, cabinets, and scrolls is not uncommon. Therefore, regular inspections and preventive maintenance services should be performed on all equipment.

Responsibility

Under the direction of the Air Installations Office the maintenance personnel of the refrigeration and air-conditioning shop are responsible for carrying out regularly scheduled routing inspections and preventive maintenance services on all evaporative coolers. Inspections and services should be scheduled to permit only a minimum of interference with the activities of the using organization. If such activities hinder the completion of servicing on one trip, the work should be completed as soon afterwards as practicable.

Inspection and preventive maintenance services should be scheduled on a master chart in the refrigerating and air-conditioning shop. This procedure will insure that each cooler is inspected and maintained at the proper time, and that repairs are made before breakdown.

Preventive Maintenance and Inspections

Definite procedures for the preventive maintenance of refrigerating and air-conditioning equipment are necessary for efficient and safe operation. The objectives of preventive maintenance are as follows: to prevent breakdown, to insure proper maintenance, to provide immediate and adequate minor repairs and avoid major repairs, to control maintenance costs, to establish specific personnel assignments, and to develop minimum but adequate maintenance records and data.

Well-planned inspections and up-to-date and correct records are required for a successful preventive maintenance program. Inspection is a key phase of preventive maintenance. It is a simple fact that when minor deficiencies are overlooked, they can cause major breakdowns in the future. This eventually defeats any preventive maintenance program. The responsibility of detection is the duty of all personnel assigned to preventive maintenance.

The technical procedures followed by a crew or team in performing inspection and maintenance on equipment should be thorough. All deficiencies must be corrected as they are detected by the various members of the crew. The important things to look for during inspections are minor deficiencies which, if not corrected immediately, will result in more costly repairs in the future. Remember--in preventive maintenance--the little things are eventually the big things.

Servicing Components

The following paragraphs contain instructions which will serve as guide procedures for inspecting and servicing the components of evaporative air cooling equipment. It may be necessary to supplement these instructions and procedures with the manufacturer's instructions where the equipment is not standardized in design.

FILTER PADS. Filter pads are maintained as clean as possible for maximum effectiveness. This maintenance is accomplished by washing the pads to remove algae, water solids, pollen, and other deposits. A garden hose with an adjustable nozzle should be used to wash filter pads. After the pads are washed thoroughly, all loose foreign materials should be washed from the water collecting tank through the drain connection. The pads should be inspected for thick sections of filter after washing. If a pad cannot be cleaned adequately, or if the thin layer cannot be corrected by fluffing the fibers from the adjacent thick sections, replace the pad with a new one. Normally, it is better to replace drip pads twice each cooling season, rather than to try prolonging their use by special cleaning methods.

Spray pads usually last a complete cooling season because continuous washing of the pads reduces the deposits of water solids, dust, and the growth of algae on glass fiber surfaces.

Spun glass fibers accumulate water solids, which form an incrustation around the fibers and reduce their effectiveness in maintaining an affinity for water. When excessive dirt and solids accumulate on the fibers, the pads should be replaced. The sagging of glass fibers in the spray pads, particularly at the top sections, also necessitates the replacement of pads. Since the fibers are enclosed in a wire mesh, they cannot be fluffed to obtain uniform sectional thickness.

The pad frame and the retaining screens should be wire-brushed to remove dirt and scale and then painted with rust-resistant paint. Screen eliminators made up of layers of wire screen should be cleaned and painted whenever excessive dirt, scale, or rust accumulate on them.

WATER DISTRIBUTORS. Proper water distribution and thoroughly saturated pads are essential to maximum efficiency from an evaporative air cooling unit. Drip distributors admit water to the top pad surface at a rate sufficient to wet the entire pad. Streams of water should flow down the outside pad surface. The water trough should be level so that approximately the same number of drops of water fall from the weir along the entire length of the trough. The troughs are usually slotted so they can be leveled. Troughs and weirs should be cleaned by wire-brushing and repainted with rust-resistant paint. The piping system should be disassembled and wire-brushed internally when excessive scale formation starts to retard the water flow.

Spray nozzles are designed to provide sufficient water to wash the pads and form an effective spray curtain in the entering airstream. Spray from each nozzle or jet must have a well-defined pattern. Spray nozzles should be cleaned by reaming out the openings. Slot jets may be cleaned by means of a thin blade made to fit the slot. A salvaged hacksaw blade with dulled teeth and no set may be used. Take care when you are cleaning the openings and slots to prevent cutting their metal edges and ruining them.

You should check rotary disk water distributors for freedom of shaft rotation and then lubricate them. The surface of the disk should be wire-brushed to remove the scale. The position of the water supply pipe in relation to the disk should be checked carefully and its position adjusted and locked at the exact location recommended by the manufacturer to insure a maximum washing and spray effect. Spray nozzles, jets, and rotary disks which cannot be cleaned satisfactorily by wire-brushing should be removed and cleaned by immersion in a 10 percent inhibited commercial hydrochloric (muriatic acid) solution.

Water pressure at the spray nozzles and jets varies with the different units. The water pressure may usually be checked at the pump discharge outlet by attaching a pressure gage to the fitting provided for this purpose. The pump discharge pressure for effective water spray and atomization should be maintained at the value recommended by the manufacturer.

WATER FLOAT VALVE. The water makeup float valve should be checked for freedom of movement, and any binding of the float lever should be corrected. The water valve should be checked for positive water cutoff, since its position determines the proper water operating level. If an adjustment is required, raise or lower the float-ball position with respect to the lever pivot. The water level should be set to permit a constant overflow for bleedoff into the overflow standpipe. The wing nut on the adjustment screw should be turned lightly in place to insure that the float-ball lever is locked in position. Float balls made of ferrous metal which are rusted should be replaced by float balls made of nonferrous metal or of plastic materials.

WATER CIRCULATING PUMPS. Because of the light construction of water circulating pumps used with evaporative drip units, they must be carefully maintained. The low oil capacity of the bearings on the motor requires frequent addition of the correct grade of oil. If the oil does not flow readily into the oil filler tubes, they should be removed and cleaned. If the stoppage appears to be in the bearing, the entire pump assembly should be removed and the bearings washed out and filled with the proper amount of oil. The impeller and interior of the casing should be cleaned of excessive scale by wire-brushing. The pump shaft and impeller should be adjusted to avoid its binding against the water intake opening or pump casing. Rusted surfaces should be wire-brushed and repainted with rust-resistant paint. When repairs are required, pumps of this type are generally taken to the shop to facilitate service work. Sufficient replacement pump assemblies should be made available for the exchange of pumps requiring repairs. Maintenance men should carry one or two pump assemblies with them to expedite service.

The misalignment of the belt drive on larger pumps used with spray units causes excessive wear and necessitates the replacement of bearings. For this reason, drives should be carefully aligned when the pump or the motor is serviced. Grease-packed ball bearings should be cleaned and repacked with the correct grade of grease every year. Graphite-impregnated bearings normally do not require lubrication. Where grease cups are used, they should be screwed down slightly every month. This should be done carefully, as the use of too much grease or oil causes the lubricant to overflow into the water and contaminate the pads. The shift packing glands of pumps should be tightened just enough to permit an occasional drop of water to escape through them. Pumps which are not readily accessible to permit easy servicing are relocated; in some cases, it may be necessary to reinstall the pump outside the unit.

CABINET AND WATER MAKEUP TANK. The exterior surfaces of the cabinet and water makeup tank which develop rust spots should be wire-brushed and given a coat of rust-resistant paint. After wire-brushing and cleaning the rusted areas, the panel interior surfaces should be painted with asphalt-base paint. The interior surfaces of both of the panels forming the water spray chamber and of the interior of the water makeup tank should be painted with asphalt-base paint. The air intake louvers and screens should be wire-brushed and cleaned so that they are free of dust, insects, and scale. Bent or distorted vanes should be straightened and repaired. Metal louvers and screens should be repainted as required.

In order to reduce excessive concentration of solids on the fibers of the water evaporating filter pads, to retard algae growth and to reduce the replacement requirements of pads and water recirculating pumps, washing services should be performed every week on each unit and immediately after heavy dust storms. All foreign materials should be washed into the water makeup tank, from which the water and sludge should be drained. With regular washing services and by cleaning strainers, screens, and nozzles, chemical treatment of the makeup water is not required.

ELECTRIC MOTORS. Electric motors used in evaporative cooling units should be properly maintained to increase their life. The exterior surfaces should be kept clean. They should be protected from excessive moisture. Moisture deteriorates the insulation on the windings of the field coils and armature. It is sometimes advisable to shield or relocate a motor if it is in the path of excessive moisture. Motors mounted on the exterior of cooling units should be protected from weather elements by some type of shield.

At least once each year, you should disassemble, inspect, and overhaul the motor. Clean it with an Air Force-approved cleaner. Compressed air may be used in conjunction with the cleaner, but you should exercise care not to damage the insulation by direct blasts.

Inspect all bearings for wear. Excessive bearing wear causes the armature to drag against the field coils, thus damaging the armature as well as the coils. If the bearings are worn beyond the limits recommended by the manufacturer, you should replace them. Lubricate all motor bearings according to the directions in the pertinent service manual.

The successful operation of motors depends to a great extent on the proper maintenance of the brushes. Brushes must not stick in the brush holders. To clean brushes and brush holders, wash them in an Air Force-recommended cleaner. If they are caked with any hard substance, remove it by sanding the brushes with fine sandpaper glued to a flat piece of wood. If the inside of a brush holder shows signs of roughness, it should also be sanded smooth before the brushes are replaced. Remember that brushes should be replaced before they wear to the extent that the copper lead connections are in danger of coming in contact with the commutator or sliprings.

BLOWER WHEELS. Inspect the blower wheel for proper alignment and freedom of rotation, and repair bent vanes. Also check axial clearance to insure there is no binding of the wheel in the scroll. Axial clearance adjustment is made by relocating the position of the shaft thrust collar. Total axial movement of the shaft after final adjustments should be approximately 1/32 inch. The thrust collar is locked in place with a thrust collar setscrew. If the thrust washers indicate considerable wear, they should be replaced. Normally, blower shaft sleeve bearings are lubricated with oil, while ball bearings are grease-packed. Grease cups are usually refilled once very year. When there is evidence of water carryover, reduce the blower speed so that the volume of the air delivered does not exceed the designed capacity of the unit. Surfaces showing excessive rusting should be cleaned, wire-brushed, and given a coat of rust-resistant paint.

If the blower is driven by a belt, inspect the belt to make sure that it is not worn, cracked, or frayed. Check it for proper tension, and check the alignment of the pulleys. The belt is properly adjusted when it can be deflected 1/2 to 3/4 inch from normal position without undue pressure at a point midway between the pulleys.

PLATFORMS AND STRUCTURES. The maintenance and repair of the platforms and structures supporting evaporative cooling units should be performed at regular intervals. Since most of these structures are constructed of dimensional lumber, each part should be inspected for rot. Check the service ladder and the rungs. Also check the railing for sturdiness.

MAJOR REPAIRS. Major repairs and renovation of evaporative air cooling units should be accomplished during the winter season every year. At bases where there are a great many units to maintain, the shop space should be sufficient to permit proper repair of the units. Smaller units can be removed from their platforms and taken into the shop as self-contained units. Since large units are not readily movable, their component parts should be removed to the shop. All units should be dismantled every year, thoroughly overhauled, cleaned, and painted to prevent rust. It is best that fans be dismantled and wheels and scrolls cleaned and painted both inside and outside. Casings, pad frames, eliminators, water makeup pans and metal structural parts should be cleaned and painted. Pads should be replaced as required. The best practice is to see that the water distributing system and the spray pump are dismantled and inspected for cleanliness or excessive impeller wear. Badly worn impellers should be replaced. All bearings on the fans, pumps, and motors must be cleaned, checked for wear, and replaced when necessary. All the ball bearings should be repacked with grease and the sleeve bearings lubricated with oil or grease as necessary. It is approved practice that units, when repaired, be replaced on their stands and their air intake louvers suitably covered to prevent the pads and the equipment from becoming dust-laden.

When new or inactive evaporative air cooling units are to be placed in service, the Air Installations maintenance personnel perform startup services to prepare the equipment for operation. Before starting the equipment, all parts, accessories, and equipment are inspected to see that they are secure and correctly adjusted. Seasonal startup is usually scheduled well ahead of the time the equipment is to be used to allow ample time for inspection and startup services.

Inspections and preventive maintenance services are designed to detect and correct hidden defects in equipment before operation becomes unsatisfactory or major failures occur. These services are scheduled for each item of equipment at a definite time. This procedure assures that each unit is given the proper care and attention as required.

QUESTIONS

1. What is preventive maintenance?
2. Who is responsible for the inspection and service of evaporative air coolers?
3. How should an evaporative air cooler be cared for during the winter season?
4. What maintenance should be performed on filter pads?
5. How should distribution troughs and weirs be cleaned?
6. What procedures should be followed in the maintenance of water spray nozzles?
7. What checks should be made on the water makeup float valve?
8. What maintenance should be performed on water circulating pumps?
9. How should rust spots in a water makeup tank be reconditioned?
10. What items should be maintained on electric motors?
11. What maintenance should be performed on blower assemblies?
12. When should major repairs on evaporative air coolers be performed?

REFERENCES

1. AFM 85-18, Maintenance and Operation of Refrigeration, Air Conditioning, Evaporative Cooling and Mechanical Ventilating Systems
2. Modern Refrigeration and Air Conditioning, Althouse, Turnquist, Bracciano

669

WORKBOOKS

3ABR54530-IX-1-P1 thru IX-4-P2

Technical Training

Refrigeration and Air-Conditioning Specialist

EVAPORATIVE COOLING SYSTEMS, COMMUNICATIONS SECURITY PUBLICATIONS, AND CIVIL ENGINEERING MAINTENANCE MANAGEMENT

December 1975

USAF SCHOOL OF APPLIED AEROSPACE SCIENCES
Department of Civil Engineering Training
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MAJOR COMPONENTS OF EVAPORATIVE COOLERS

OBJECTIVE

Using a schematic, identify the components and trace the flow of air and water through the evaporative cooler.

INSTRUCTIONS

Match the numbers on the diagram below with the proper name of that component.

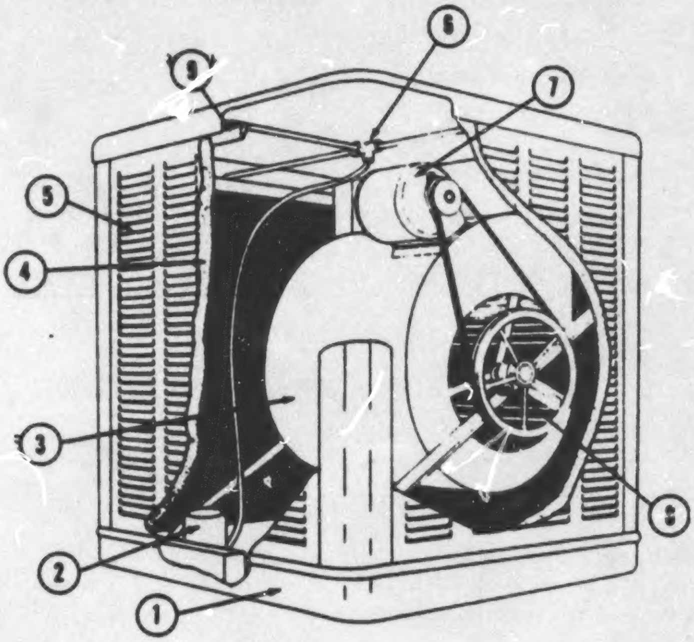

Figure 1. Evaporative Cooler

________ Blower Wheel
________ Corner Post
________ Top Pan
________ Motor
________ Bottom Pan
________ Blower Housing
________ Bleed Cock
________ Excelsior Pad

________ Water Distribution Trough
________ Water Soaker
________ Circulation Pump
________ Air Recirculator
________ Front Panel
________ Louvered Frame
________ Water Distributor

Checked by________________________
Instructor

PREOPERATION AND OPERATION OF EVAPORATIVE COOLERS

OBJECTIVE

Using the evaporative cooler, perform a preoperational check and operate the system.

> Note: The instructor will determine whether this exercise is performed individually or by groups.

Follow the preoperational checklist below and answer all questions in the spaces provided.

1. Check source of power.

   Volts ____________________

   Will the unit operate if power is applied? ____________________

2. Check cooling unit pads for sagging.

   What material is normally used to manufacture cooling pads? __________

   ____

3. Check circulation pump screen for obstructions.
4. Check drive motor for alignment and mounting.
5. Check drive belts for alignment and serviceability.
6. Connect cooling unit to water supply.
7. Check float valve operation.
8. Turn water on and check pan water level.

   What should the water level be? ____________________

   ____

9. Connect cooling unit to power source. (CAUTION: Insure that power is off.)
10. Turn unit ON. (CAUTION: Stand clear of supply air duct.)

11. Remove side panel and check water distribution.

How is the proper water distribution maintained? ______________________

____

12. Have instructor check your work.

13. Turn unit OFF.

Checked by ______________________
Instructor

COMMUNICATION SECURITY

OBJECTIVE

Upon completion of this workbook you should be able to:

Determine the purpose of the Air Force Security Program.

Identify the three categories of security classifications.

Establish the requirements for being granted access to classified material.

Methods of handling classified material.

Select Air Force Regulation that outlines procedures for handling classified material.

INSTRUCTIONS

Complete the workbook by entering the correct information in the spaces provided.

1. ________________, ________________, ____________________ are the three categories assigned to classified material in their order of importance.

2. Information or material the defense aspect of which is paramount, and the unauthorized disclosure of which could result in exceptionally grave damage to the nation would be classified ____

3. You must have a need to know, be deemed trustworthy and have ____________ ____________ prior to being granted access to classified information.

4. Classified information handling and safeguarding of is governed by what publication? ____

5. The three main concerns in the proper handling of classified information are; ________________, ________________, ____________________, ________________________

6. Safeguarding information and material vital to the welfare of the nation describes what? ______________ ______________ ______________ ______________ ______________ ______________

7. A person must have been granted a __________________ __________________ ________________________________ for access to the category of information involved in order to be deemed trustworthy.

8. Classified material can be destroyed by __________________________________ or ______________________________ to pulp by or in the presence of ________________ ______________________________ designated officials.